HYDRAULICS

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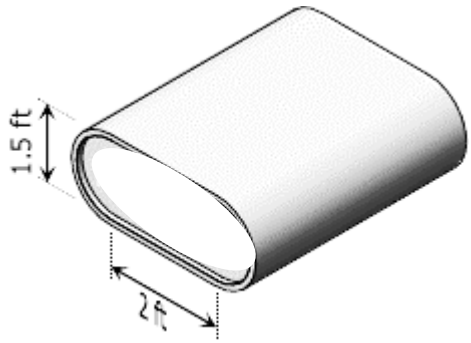
A. Thin-walled Pressure Vessel

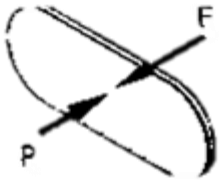
1. **The tank shown in Fig. is fabricated from 1/8-in steel plate. Calculate the maximum longitudinal and circumferential stress caused by an internal pressure of 125 psi.**



Solution

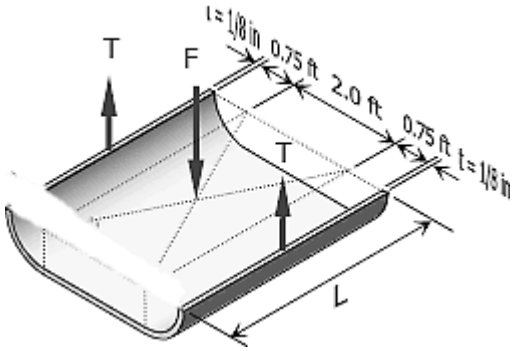
Longitudinal Stress:

F=PA
F=125[1.5(2)+14π(1.5)2](122)
F=85808.62lbs



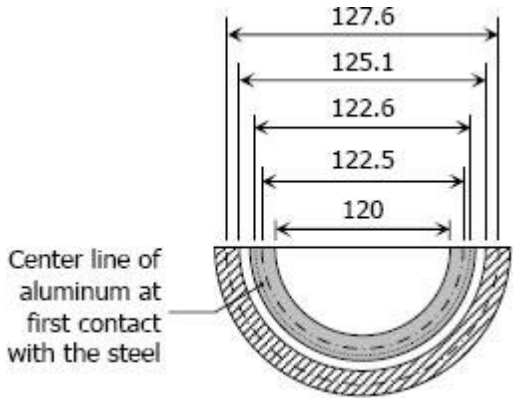
P=F
σl[2(2×12)(18)+π(1.5×12)(18)]=85808.62
σl=6566.02psi
σl=6.57ksi

Circumferential Stress:
F=pA=125[(2×12)L+2(0.75×12)L]
F=5250L lbs

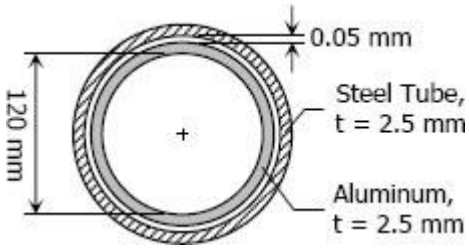


2T=F
2[σt(18)L]=5250L
σt=21000psi
<u>σt=21ksi</u>

2. **There is a radial clearance of 0.05 mm when a steel tube is placed over an aluminum tube. The inside diameter of the aluminum tube is 120 mm, and the wall thickness of each tube is 2.5 mm. Compute the contact pressure and tangential stress in each tube when the aluminum tube is subjected to an internal pressure of 5.0 MPa.**



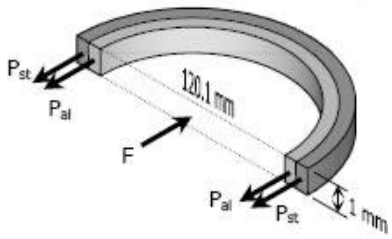
Internal pressure of aluminum tube to cause contact with the steel:
δal=(σLE)al
π(122.6−122.5)=σ1(122.5π)70000π



σ1=57.143MPa
p1D2t=57.143
p1(120)2(2.5)=57.143

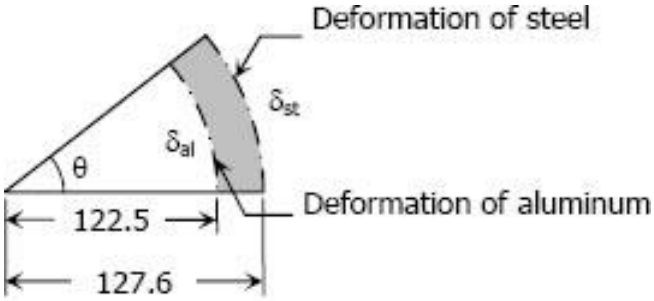
p1=2.381 MPa→ pressure that causes aluminum to contact with the steel, further increase of pressure will expand both aluminum and steel tubes.

Let p_c = contact pressure between steel and aluminum tubes



2Pst+2Pal=F
2Pst+2Pal=5.0(120.1)(1)
Pst+Pal=300.25 → Equation (1)

The relationship of deformations is (from the figure):
δst=127.6θ
θ=δst/127.6



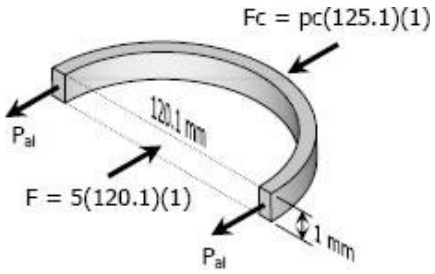
Geometric relation of deformations

δal=122.5θ
δal=122.5(δst/127.6)
δal=0.96δst
(PLAE)al=0.96(PLAE)st
Pal(122.5π)2.5(70000)=0.96[Pst(127.6)2.5(200000)]
Pal=0.35Pst → Equation (2)

From Equation (1)
Pst+0.35Pst=300.25
Pst=222.41N

From Equation (2)
Pal=0.35(222.41)
Pal=77.84N

Contact Force

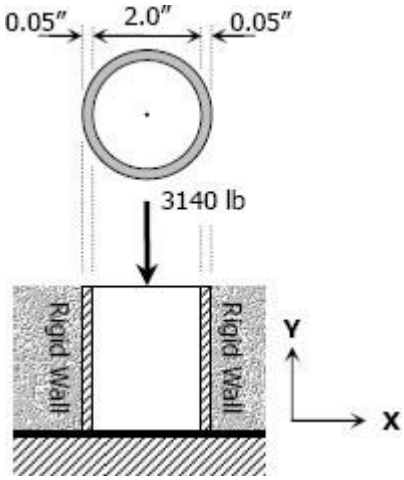


Fc+2Pst=F

pc(125.1)(1)+2(77.84)=5(120.1)(1)

pc=3.56 MPa

3. **A 2-in.-diameter steel tube with a wall thickness of 0.05 inch just fits in a rigid hole. Find the tangential stress if an axial compressive load of 3140 lb is applied. Assume ν = 0.30 and neglect the possibility of buckling.**



$\varepsilon_x=\sigma_xE-\nu\sigma_yE=0$

$\sigma_x=\nu\sigma_y$

Where

σ_x = tangential stress

σ_y = longitudinal stress

$\sigma_y = P_y / A = 3140 / (\pi \times 2 \times 0.05)$

$\sigma_y = 31{,}400/\pi$ psi

Thus,

$\sigma_x=0.30(31400/\pi)$

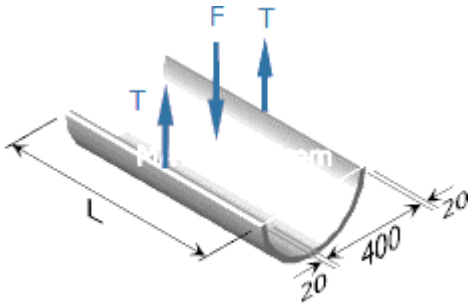
$\sigma x=9430/\pi$ psi

$\underline{\sigma x=2298.5 \text{ psi}}$

4. **A cylindrical steel pressure vessel 400 mm in diameter with a wall thickness of 20 mm, is subjected to an internal pressure of 4.5 MN/m². (a) Calculate the tangential and longitudinal stresses in the steel. (b) To what value may the internal pressure be increased if the stress in the steel is limited to 120 MN/m²? (c) If the internal pressure were increased until the vessel burst, sketch the type of fracture that would occur.**

Part (a)

Tangential stress (*longitudinal section*):



Longitudinal Section

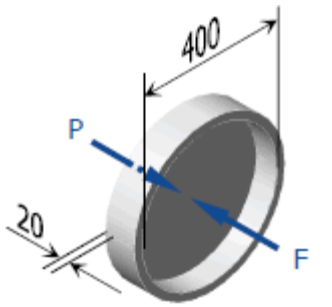
F=2T

pDL=2(σttL)

σt=pD2t=4.5(400)2(20)

σt=45MPa

Longitudinal Stress (*transverse section*):



Transverse Section

F=P

14πD2p=σl(πDt)

σl=pD4t=4.5(400)4(20)

σl=22.5MPa

Part (b)

From (a), $\sigma_t = pD2t$ and thus, $\sigma_t = 2\sigma_l$, this shows that tangential stress is the critical.

$\sigma t = pD2t$

$120 = p(400)2(20)$

$\underline{p = 12MPa}$

5. **Calculate the minimum wall thickness for a cylindrical vessel that is to carry a gas at a pressure of 1400 psi. The diameter of the vessel is 2 ft, and the stress is limited to 12 ksi**

The critical stress is the tangential stress

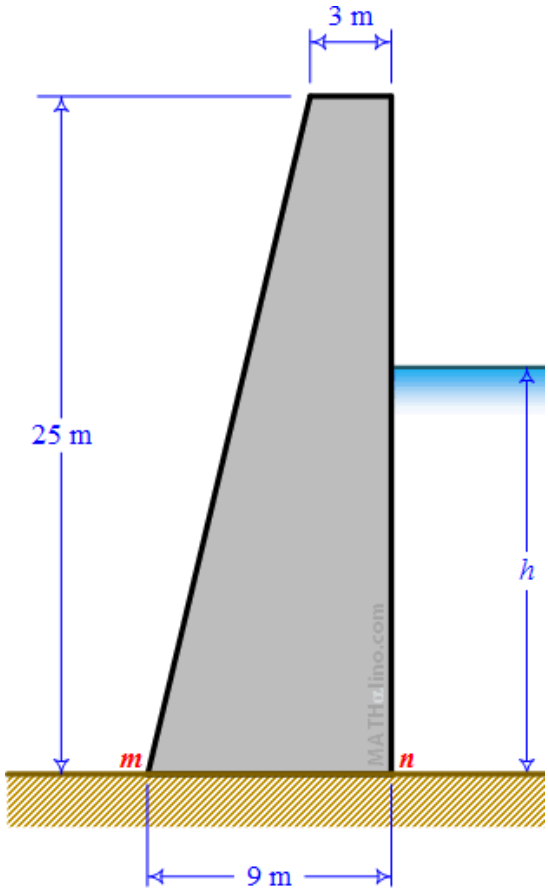
$\sigma_t = pD2tt$

$12000 = 1400(2\times12)2t$

$\underline{t = 1.4\ in}$

B. Dams

1. A concrete dam has the profile shown in Figure. If the density of concrete is 2400 kg/m³ and that of water is 1000 kg/m³, determine the maximum compressive stress at section *m-n* if the depth of the water behind the dam is h = 15 m.

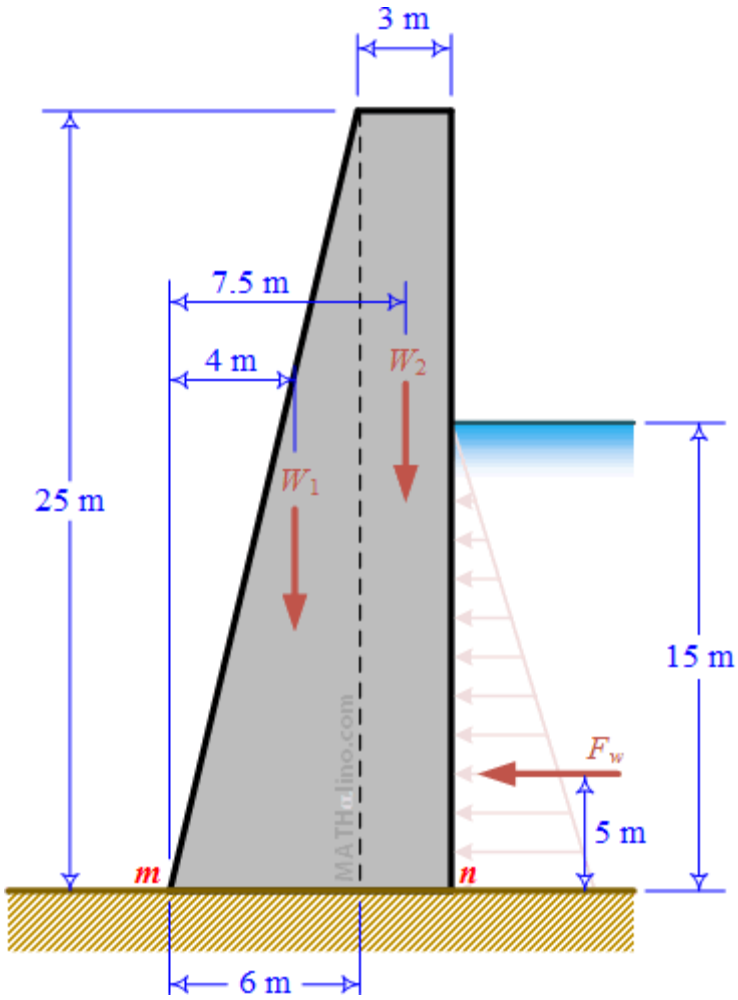


Consider 1-m length perpendicular to the drawing

$$W_1 = 2400 \times \frac{1}{2}(6)(25)(1)$$
$$W_1 = 180{,}000 \text{ kg}$$

$$W_2 = 2400 \times 3(25)(1)$$
$$W_2 = 180{,}000 \text{ kg}$$

$$F_w = 1000(7.5) \times 15(1)$$
$$F_w = 112{,}500 \text{ kg}$$



Moment About *m*

Righting Moment, *RM*

$$RM=4W_1+7.5W_2=4(180,000)+7.5(180,000)$$

$$RM=2,070,000\ kg\cdot m$$

Overturning Moment, *OM*

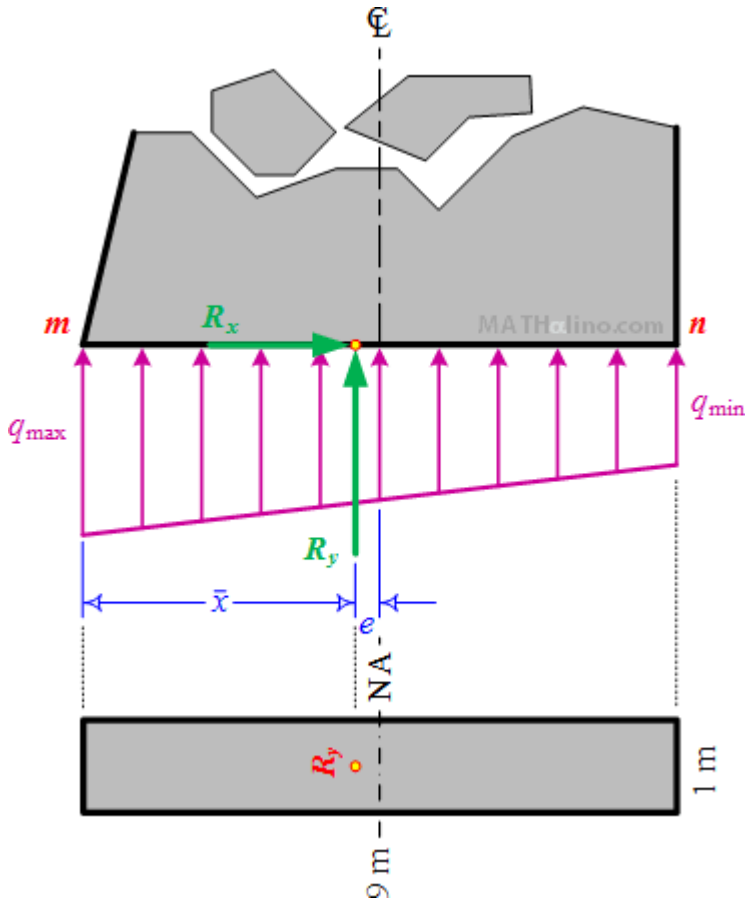
$$OM=5F_w=5(112,500)$$

$$OM=562,500\ kg\cdot m$$

Reactions at the Base

$$R_y=W_1+W_2=360,000\ kg$$

$$R_x=F_w=112,500\ kg$$



Location of R_y

$$\bar{x}R_y = RM - OM$$

$$\bar{x}(360{,}000) = 2{,}070{,}000 - 562{,}500$$

$$\bar{x} = 4.1875 \text{ m}$$

Eccentricity

$$e = 4.5 - \bar{x} = 4.5 - 4.1875$$

$$e = 0.3125 \text{ m}$$

$$M = R_y e = 360{,}000(0.3125)$$

$$M = 112{,}500 \text{ kg-m}$$

$$\sigma_a = \frac{P}{A} = 360{,}000\frac{1}{(9)}$$

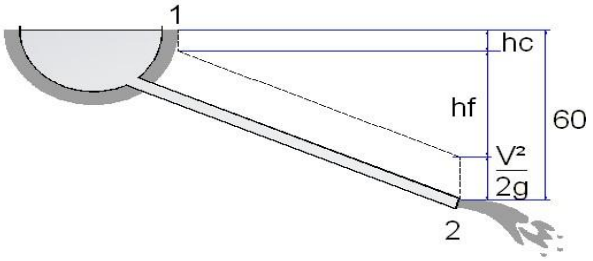
$$\sigma_a = 40{,}000 \text{ kg/m}^2$$

$$\sigma_f = \frac{6M}{bd^2} = 6(112{,}500)\frac{1}{(9^2)}$$

σ_f=8,333.33 kg/m2

$q_{max}=\sigma_a+\sigma_f$=40,000+8,333.33
q_{max}=48,333.33 kg/m2

`A 20cm diameter pipe of length 100m with z = 60m with f = 0.02 and loss of head due to entrance coefficient k = 0.5. What is the flow rate?



Solution:

$$60 = hc + hf + \frac{V_2^2}{2g}$$

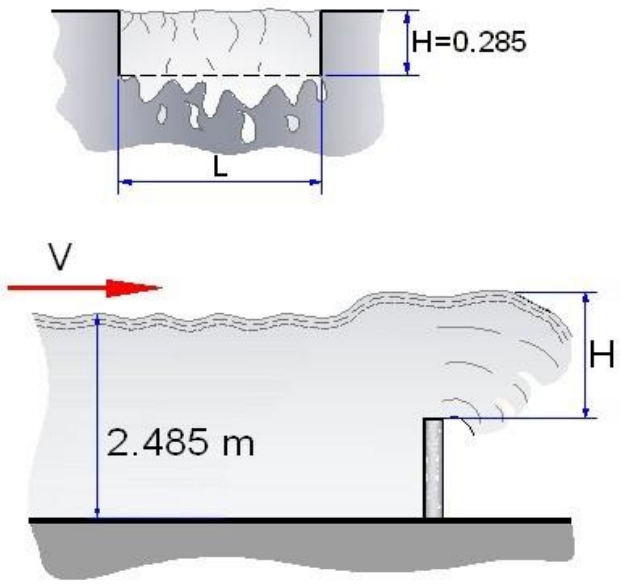
$$60 = \frac{kc\,V_2^2}{2g} + \frac{fL\,V_2^2}{D\,2g} + \frac{V_2^2}{2g}$$

$$60 = \frac{0.50\,V_2^2}{2g} + \frac{0.02(100)\,V_2^2}{0.2(2)\,g} + \frac{V_2^2}{2g}$$

$$\frac{V_2^2}{2g} = 5.22$$

$$V = 10.12\ m/s$$

Find the width in m of the channel at the back of a suppressed weir using the following data: H = 28.5cm; d = 2.485m; Q = 0.84 cu.m/sec. Consider the velocity of approach and use the Francis formula.



Solution:

$$Q = 1.84L\left[(H + hv)^{3/2} - hv^{3/2}\right]$$

$$hv = \frac{V^2}{2g}$$

$$V = \frac{Q}{A}$$

$$V = \frac{0.84}{2.485L}$$

$$V = \frac{0.338}{L}$$

$$hv = \frac{0.114}{L^2\,2g}$$

$$hv = \frac{0.0058}{L^2}$$

$$0.84 = 1.84L\left[\left(0.285 + \frac{0.0058}{L^2}\right)^{3/2} - \left(\frac{0.0058}{L^2}\right)^{3/2}\right]$$

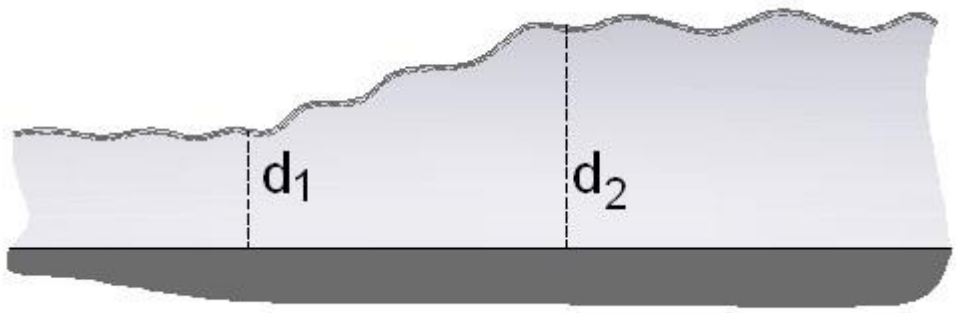
Try $L = 3$

$$0.84 = 1.84(3)\left[(0.285 + 0.00064)^{3/2} - (0.00064)^{3/2}\right]$$

$0.84 = 0.842$

Use $L = 3$

Water flows in a 2m. wide rectangular flume at the rate of 2.75 cu.m./sec. with a mean velocity of 3.5 m/s. To what depth, in cm., can the water jump? Use g = 9.81



Solution:

$$q = \frac{2.75}{2}$$

$$q = 13975° \; cu.m/\sec/m$$

$$\frac{q^2}{g} = d_1 d_2 \frac{\left(d_1 + d_2\right)}{2}$$

$$q = A_1 V_1$$

$$1.375 = d_1 (1)(3.5)$$

$$d_1 = 0.39$$

$$\frac{(1.375)^2}{9.81} = 0.39 d_2 \frac{\left(0.39 + d_2\right)}{2}$$

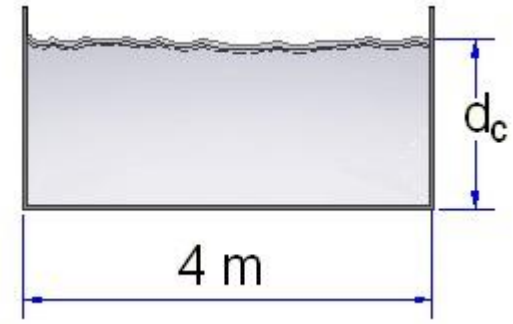
$$0.99 = 0.93 d_2 + d_2^2$$

$$d_2 = 0.818 m.$$

$$d_2 = 81.8 cm.$$

A rectangular concrete flume, 4m wide, carries water at the rate 5 cu.m/sec.

Determine the critical depth in m. Use g = 9.81.



Solution:

$$q = \frac{5}{4}$$

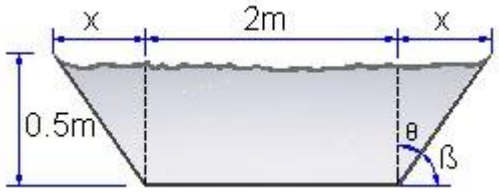
$$q = 1.25\ cu.m/sec/m$$

$$d_c = \sqrt[3]{\frac{q^2}{g}}$$

$$d_c = \sqrt[3]{\frac{(1.25)^2}{9.81}}$$

$$d_c = 0.542\ m.$$

The length of the crest of a trapezoidal weir is 2m. The sides are slopping at 75°57'49" with the horizontal. Find the discharge in cu.m/sec if the head on the weir is 0.5m.



Solution:

$$\tan\beta = \frac{0.5}{x}$$

$$\tan 75°57'49" = \frac{0.5}{x}$$

$$x = 0.125$$

$$\tan\phi = \frac{0.125}{0.5}$$

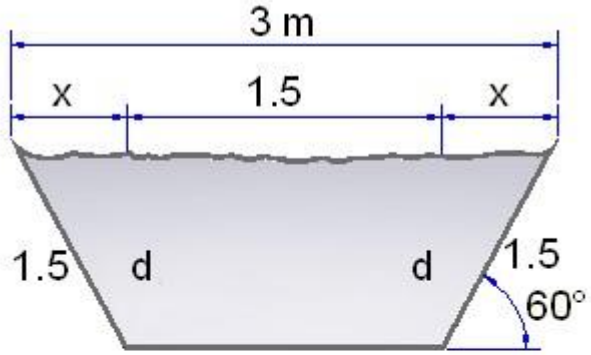
$$\tan\phi = \frac{1}{4}\left(\textit{therefore this is a Cippolletti weir}\right)$$

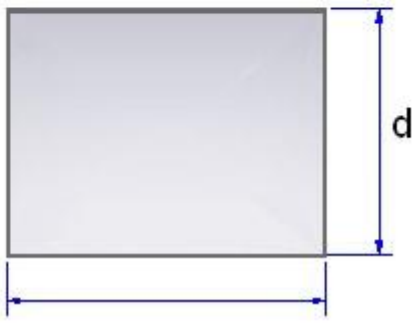
$$Q = 1.86 L H^{3/2}$$

$$Q = 1.86(2)(0.5)^{3/2}$$

$$Q = 1.32\ cu.m/sec.$$

A trapezoidal flume of most efficient proportion has a base width of 1.5m. Its full discharge is 3cu.m/sec. If the same material were used for the most efficient rectangular section, by how much would the discharge decrease in cu.m/sec.





Solution: $P = 1.5(3)$

$P = 4.5$

$Sin\,60° = \frac{d}{1.5}$

$d = 1.3\,m$

$Cos\,60° = \frac{x}{1.5}$

$x = 0.75$

$A = \frac{(3+1.5)(1.3)}{2}$

$A = 2.925$

$R = \frac{A}{P}$

$R = \frac{2.925}{4.5}$

$R = 0.65$

$Q = AV$

$3 = 2.925(0.65)^{2/3}\,\frac{S^{1/2}}{n}$

$\frac{S^{1/2}}{n} = 1.367$

For the rectangular channel:

$b + 2d = 4.5$

$b = 2d$

$2b + 2d = 4.5$

$d = 1.125$

$b = 2.25$

$A = 2.25(1.125) = 2.531$

$R = \frac{A}{P}$

$R = \frac{2.531}{4.5} = 0.5625$

$Q = AV$

$Q = 2.531(0.5625)^{2/3}\,\frac{S^{1/2}}{n}$

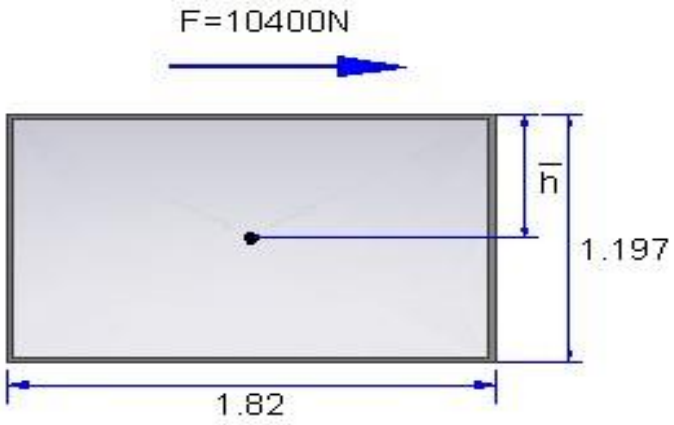
$Q = 2.531(0.5625)^{2/3}\,(1.367)$

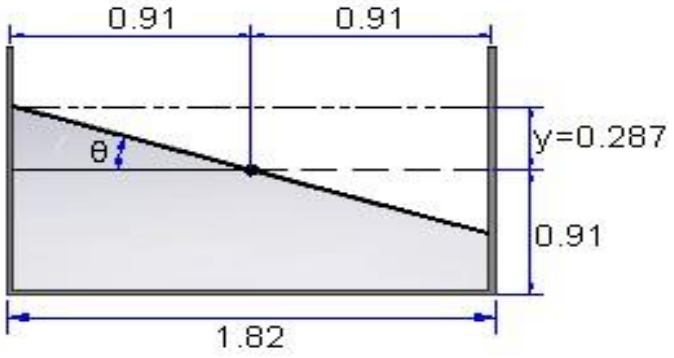
$Q = 2.36\,m^3/s$

$Decrease\ in\ discharge = 3 - 2.36$

$Decrease\ in\ discharge = 0.64\ m^3/s$

An open tank 1.82m. square, weighs 3425N and contains 0.91 m. of water. It is acted by an unbalanced force of 10400 N parallel to a pair of sides. What is the force (N) acting in the side with the greatest depth?





Solution: $F = ma$

$$F = \frac{w}{g}a$$

$$W = 3425 + 1.82(1.82)(0.91)(98100)$$

$$W = 32995.13N$$

$$10400 = \frac{32995.13a}{9.81}$$

$$a = 3.092 m/s^2$$

$$\tan\theta = \frac{a}{g}$$

$$\frac{y}{0.91} = \frac{3.092}{9.81}$$

$$= 0.287$$

$$= \frac{1.197}{2}$$

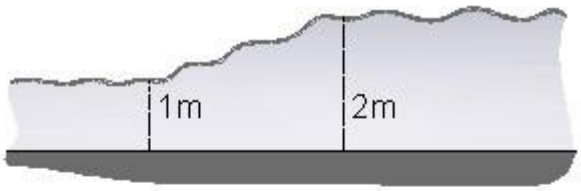
$$= 0.5985$$

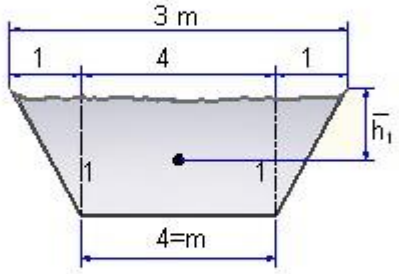
$$P = whA$$

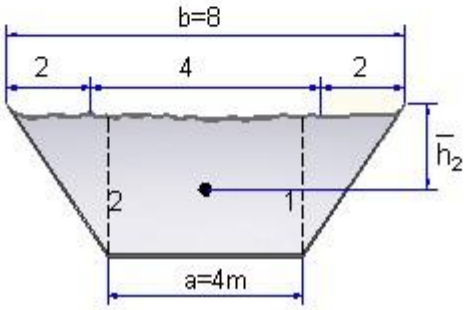
$$P = 9810(0.5985)(1.197)(1.82)$$

$$P = 12791\ N$$

Hydraulic jump occurs in a trapezoidal channel with sideslopes of 1:1 and base of 4m. If the upstream depth before the jump is 1.0m. and downstream depth is 2m., what is the discharge?







Solution:

$$\frac{Q^2}{g}=\frac{A_1h_1-A_2h_2}{\frac{1}{A_2}-\frac{1}{A_1}}$$

$$h=\frac{1}{3}\frac{(2a+b)}{(a+b)}h$$

$$h_1=\frac{1}{3}\left[\frac{2(4)+8}{4+8}\right]1$$

$$h_1=0.467$$

$$h_2=\frac{1}{3}\left[\frac{2(4)+8}{4+8}\right]2$$

$$h_2=0.889$$

$$A_1=\frac{(4+6)}{2}(1)$$

$$A_1=5m^2$$

$$A_2=\frac{(4+8)}{2}(1)$$

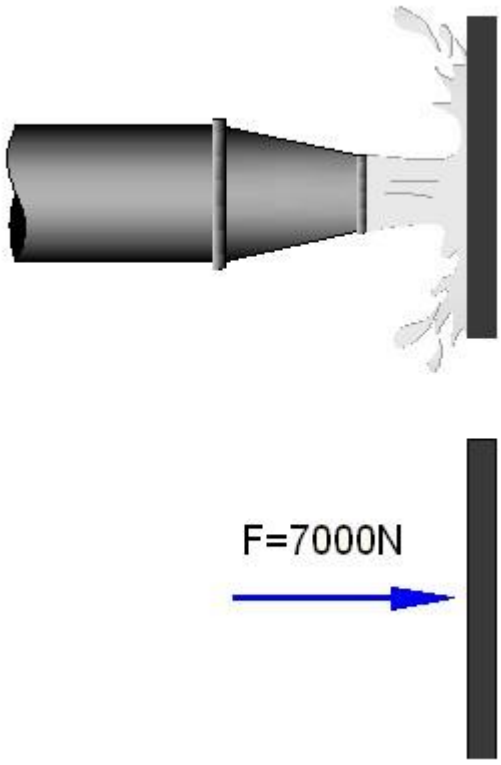
$$A_2=12m^2$$

$$\frac{Q^2}{g}=\frac{A_1h_1-A_2h_2}{\frac{1}{A_2}-\frac{1}{A_1}}$$

$$\frac{Q^2}{9.81}=\frac{5(0.467)-12(0.889)}{\frac{1}{12}-\frac{1}{5}}$$

$$Q=26.47\ m^3/s$$

The jet of a horizontal nozzle strikes a vertical plate with a force equal to 7000N. If the discharge flowing at the nozzle is 0.12 m^3/s. Compute the diameter of the jet.



Solution:

$$F = \frac{QW}{g}V$$

$$7000 = \frac{0.12(9810)V}{9.81}$$

$$V = 58.33\ m/s$$

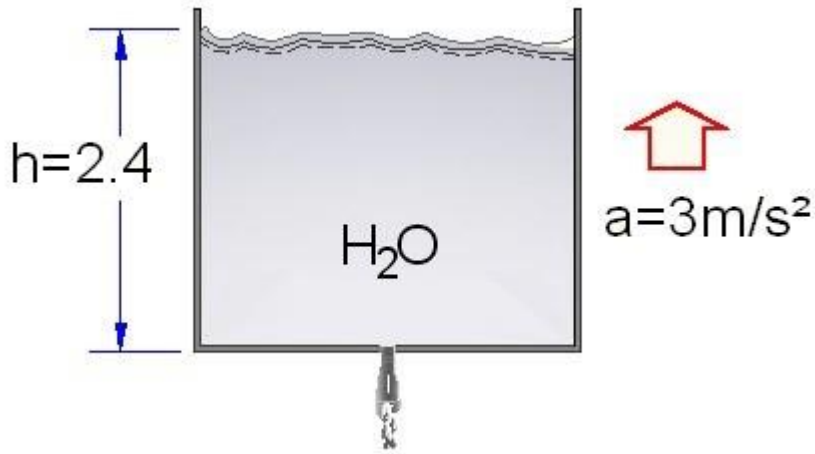
$$Q = AV$$

$$0.12 = \frac{\pi D^2}{4}(58.33)$$

$$D = 0.051\ m.$$

$$D = 51\ mm.$$

A tank filled with water to a depth of 2.4m. is accelerated upward at a rate of 3 m/s². The velocity of the discharge at the orifice 2cm. in diameter located at the bottom of the tank is:



Solution:

$$h = \left(1+\frac{a}{g}\right)$$

$$h = 2.4\left(1+\frac{3}{9.81}\right)$$

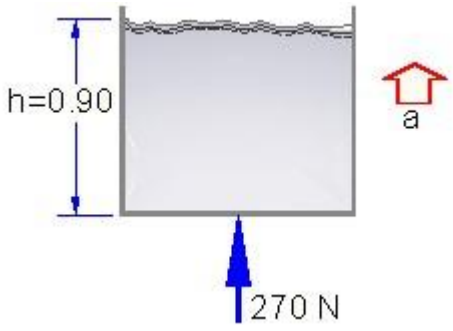
$$h = 3.13m.$$

$$V = \sqrt{2gh}$$

$$V = \sqrt{2(9.81)(3.13)}$$

$$V = 7.84\ m/s$$

An unbalanced vertical force of 270N upward accelerates a volume of 0.044 m³ of water. If the water is 0.9m. deep in a cylindrical tank, what is the force in N acting on the bottom of the tank?



Solution:

$$W_w = 0.044(9810)$$

$$W_w = 431.64\ N$$

$$F = ma$$

$$F = \frac{w}{g}a$$

$$270 = \frac{431.64}{9.81}a$$

$$a = 6.14\ m/s^2$$

$$P_b = wh\left(1+\frac{a}{g}\right)$$

$$P_b = 9810(0.9)\left(1+\frac{6.14}{9.81}\right)$$

$$P_b = 14355\ N/m^2$$

$$V = Ah$$

$$0.044 = A(0.90)$$

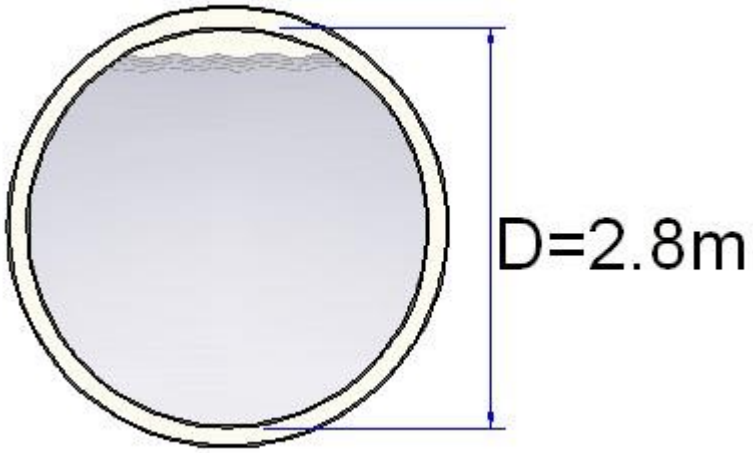
$$A = 0.0489\,m^2$$

$$P = P_b\,A$$

$$P = 14355(0.0489)$$

$$P = 702\,N$$

Determine the discharge in MLD of a 2800 mm gravity flow concrete aqueduct 4km long with a head loss of 5.6m. Assume pipe is flowing just full with roughness coeff. of 0.015.



Solution:

$$Q = AV$$

$$Q = A\frac{1}{n}R^{2/3}S^{1/2}$$

$$R = \frac{D}{4}$$

$$R = \frac{2.8}{4}$$

$$R = 0.7$$

$$S = \frac{5.6}{4000}$$

$$A = \frac{\pi(2.8)^2}{4}$$

$$A = 6.16m^2$$

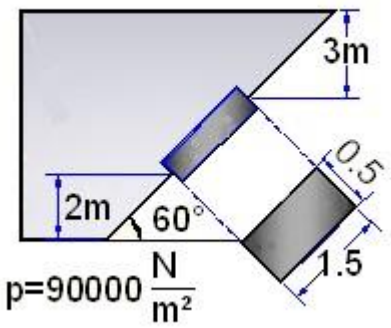
$$Q = (6.16)\frac{1}{0.015}(0.7)^{2/3}\left(\frac{5.6}{4000}\right)^{1/2}$$

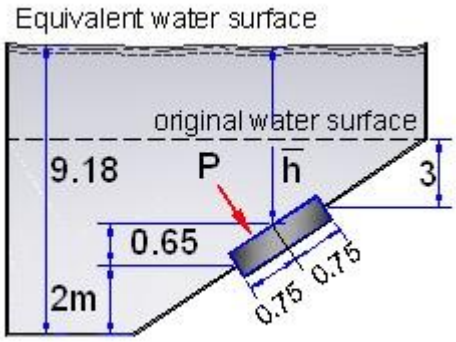
$$Q = 12.11\frac{m^3}{s}$$

$$Q = 12.11\frac{m^3}{s}x\frac{1000lit}{m^3}x\frac{3600}{1hr}x\frac{24hrs}{1day}x\frac{1million}{1x10^6liters}$$

$$Q = 1046\ M\ L\ D$$

Determine the magnitude of the force on the inclined gate 1.5m. by 0.5m. shown in the figure. The tank is completely closed and the pressure gage at the bottom of the tank reads 90000 N/m². Use 9800 N/m³ for H_2O.





sin 60 = x/1.5; x= 1.299/2 ; 0.65

Solution:

$$h_1 = \frac{P}{w}$$

$$h_1 = \frac{90000}{9800}$$

$$h_1 = 9.18$$

$$\bar{h} = 9.18 - 2.65$$

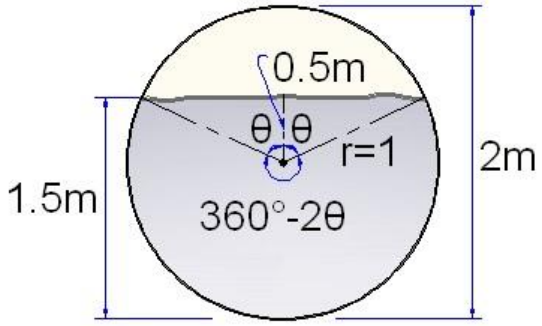
$$\bar{h} = 6.53$$

$$P = w\bar{h}A$$

$$P = 9800(6.53)(1.5)(0.5)$$

$$P = 47995.5\ N$$

A circular pipe 2m. in diameter carries water at a depth of ¾ of its diameter. What is the hydraulic radius?



Solution:

$$Cos\,\theta = \frac{0.5}{1}$$

$$\theta = 60°$$

$$2\theta = 120°$$

$$360 - 2\theta = 240°$$

$$A_{seg} = A_T + A_{sec}$$

$$A_T = \frac{1}{2}(1)(1)Sin120°$$

$$A_T = 0.433m^2$$

$$\frac{A_{sec}}{240°} = \frac{\pi(1)^2}{360°}$$

$$A_{sec} = 2.09m^2$$

$$A_{seg} = 0.433 + 2.09$$

$$A_{seg} = 2.523\,m^2$$

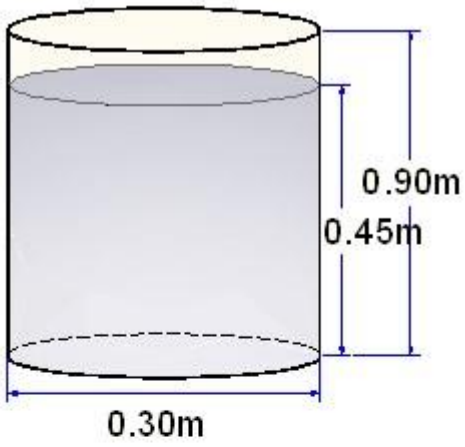
$$\frac{A_p}{240} = \frac{2\pi(1)}{360°}$$

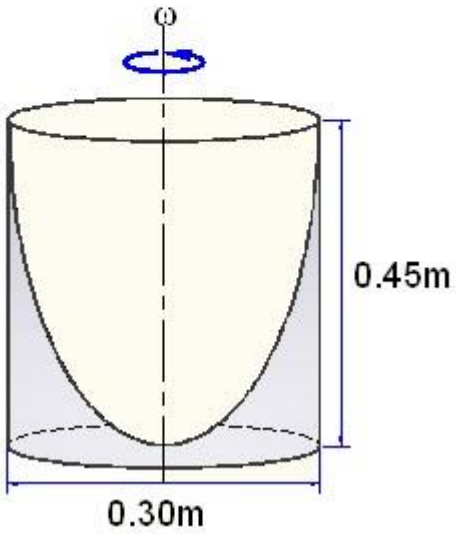
$$A_p = 4.189\,m^2$$

$$R = \frac{2.523}{4.189}$$

$$R = 0.602$$

An open vessel 30cm. in diameter and 90cm high is filled with water to a depth of 45 cm. Find the magnitude of the velocity such that the vortex is just at the bottom.





Solution:

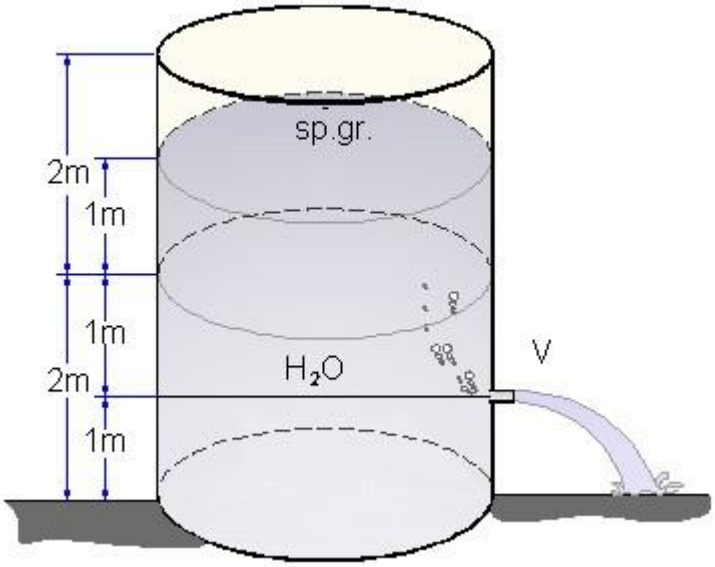
$$y = \frac{w^2 x^2}{2g}$$

$$0.90 = \frac{w^2 (0.15)^2}{2(9.81)}$$

$$w = 28.01\, rad/s$$

A large cylindrical steel tank 4m. high with its bottom on level ground contains two layers of liquid. The bottom layer is water 2m. deep. The top layer is occupied by a liquid whose specific gravity is not known to a depth of 1m. A 50 mm diam. orifice with a coefficient of velocity of 0.98 is situated one meter from the bottom of the tank. The jet from the orifice hits the ground 2.75m horizontally away from the vena contracta.

Determine the sp.gr. of the liquid.



Solution:

$$y = \frac{1}{2}gt^2$$

$$1 = \frac{1}{2}(9.81)t^2$$

$$t = 0.45 \text{ sec.}$$

$$x = Vt$$

$$2.75 = V(0.45)$$

$$V = Cv\sqrt{2gh}$$

$$6.11 = 0.98\sqrt{2(9.81)h}$$

$$\sqrt{h} = 1.408$$

$$h = 1.98\ m.$$

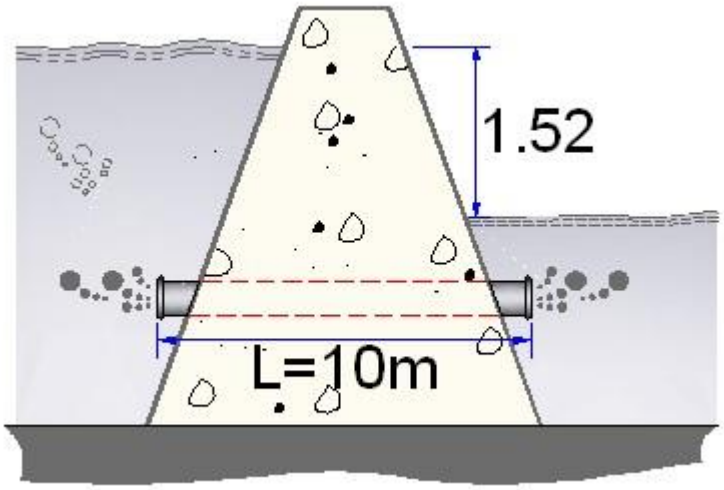
$$h = 1 + 1(sp.gr.)$$

$$sp.gr = 0.98$$

What is the discharge capacity of a concrete pipe culvert 4 ft. in diam.

And 10m. long if the difference in water level at the outlet is 10m.

Assume coefficient of discharge C = 0.74.



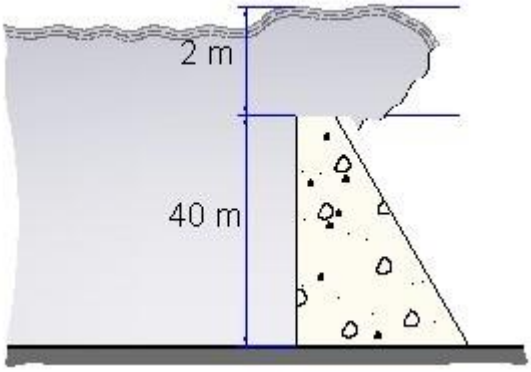
Solution:

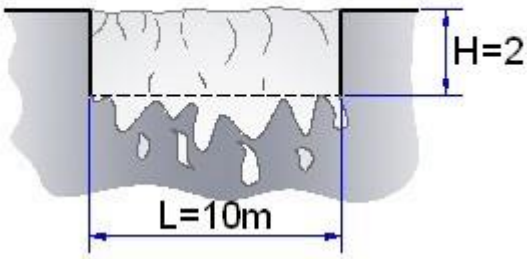
$$Q = CA\sqrt{2gh}$$

$$Q = 0.74\frac{\pi}{4}(1.22)^2\sqrt{2(9.81)(1.52)}$$

$$Q = 4.73\ m^3/s$$

A dam 40m. high has a spillway discharging at 2m. deep and a crest length of 10m. If c = 3.2, find the discharge in cu.m. sec.





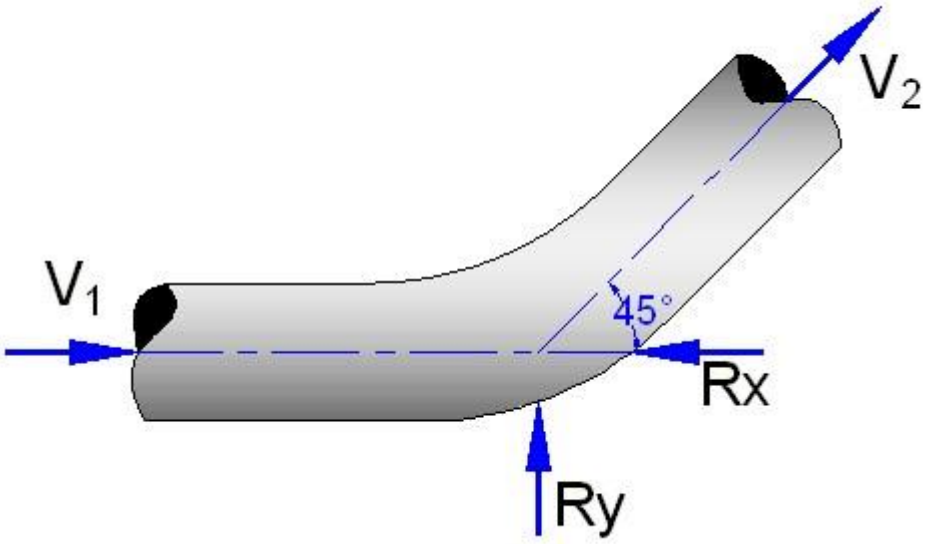
Solution:

$Q = C\,L\,H^{3/2}$

$Q = 3.2(10)(2)^{3/2}$

$Q = 90.5\ m^3/s$

A 600 mm. diameter water main is bent at an angle of 45° from the horizontal. What vertical component of dynamic pressure is developed in the bend if the velocity in the pipe is 2 m/s?



Solution:

$$Q = AV$$

$$Q = \frac{\pi}{4}(0.6)^2(2)$$

$$Q = 0.565\ m^3/s$$

$$\sum Fy = \frac{Qw}{g}\left(V_2y - V_1y\right)$$

$$Ry = \frac{0.565(9.81)}{9.81}\left(2Cos\,45° - 0\right)$$

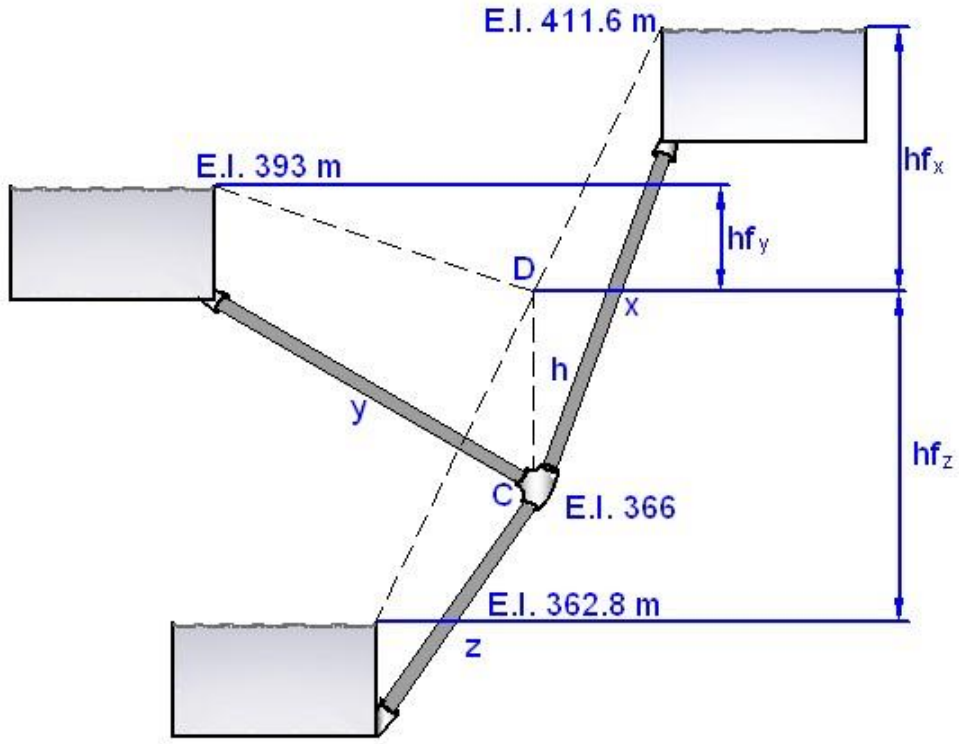
$$R_y = 0.80kN$$

Pipes from three reservoirs meet at point C which is at elevation 366 m.

Assume all pipes are PVC, with Hazen Williams C = 150. Pressure at point C is 18.3 psi.

Pipeline	Diameter(inches)	Length(ft)
x	10	10000 y
8	4000 z	12
5000		

Find the head loss of pipeline x.



Solution:

$$h = \frac{P}{W}$$

$$h = \frac{18.3(144)}{62.4}$$

$$h = 41.54\,ft.$$

$$h = \frac{41.54}{3.28}$$

$$h = 12.66m.$$

$$Elev.\ at\ D = 336 + 12.66$$

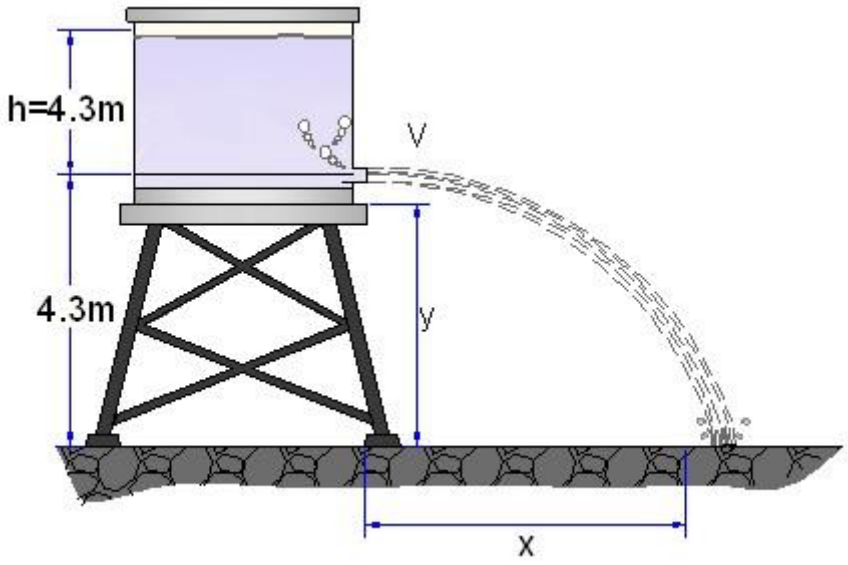
$$Elev.\ at\ D = 378.66m.$$

$$hf_x = 411.6 - 378.66$$

$$hf_x = 32.94m.$$

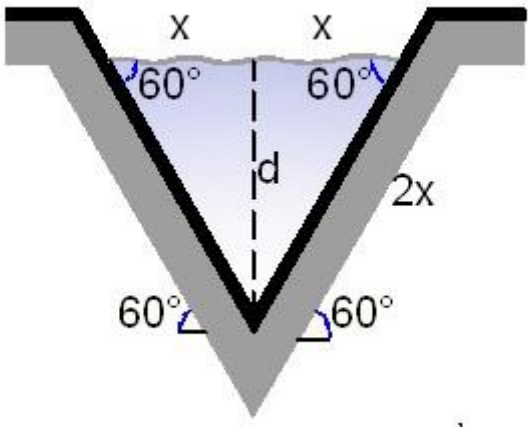
$$(head\ loss\ of\ \ pipe\ line\ x)$$

A water tank is filled with water to a height of 4.3m. above the 10 mmØ orifice which is connected at the side of the tank, how far would the water have traveled horizontally if the orifice is 4.3m. above the ground?



Solution:

Water flows in the triangular channel at a rate of 222 lites/sec. Find the depth of flow if the channel slope is 0.0008 and n = 0.016. The two sides of the channel is incline at an angle of 60° with the horizontal.



Solution:

$$\tan 60° = \frac{d}{x}$$

$$x = 0.577\,d$$

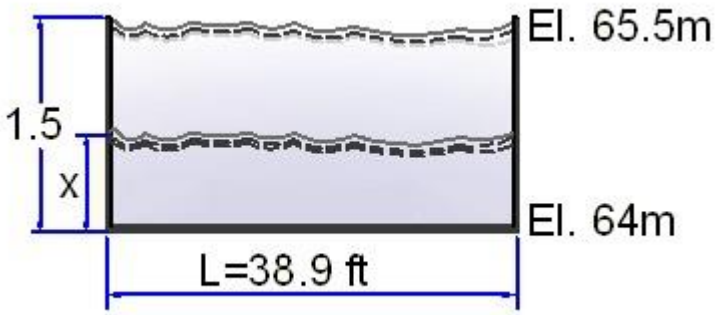
$$A = \frac{2x(d)}{2}$$

$$A = 0.577\,d^2$$

$$P = 2x + 2x = 4x$$

$$P = 4(0.577)d$$

A concrete spillway controls a reservoir having an area of 46000 sq.m. with a permanent crest elevation of 64m. and a length of crest of 38.9 ft. is drawn from elevation of the water surface after 0.70 hours. Use Francis Formula.



$$V = \sqrt{2gh}$$

Solution:

$$V = \sqrt{2(9.81)(4.3)}$$

$$V = 9.19\ m/s$$

$$x = Vt$$

$$y = \frac{1}{2}gt^2$$

$$t = \frac{x}{V}$$

$$4.3 = \frac{1}{2}\frac{(9.81)(x)^2}{(9.19)^2}$$

$$x = 8.60\ m.$$

$$t = \int_x^{1.5} \frac{As\,dh}{1.84\,L\,h^{3/2}}$$

$$0.7(3600) = \int_{0.5}^{1.5} \frac{46000h^{-3/2}\,dh}{1.84(38.9)(3.28)}$$

$$1.195 = -2h^{-1/2}\Big]_x^{1.5}$$

$$1.195 = -2\left[\frac{1}{(1.5)^{1/2}} - \frac{1}{x^{1/2}}\right]$$

$$-0.5975 = \left(\frac{1}{\sqrt{1.5}} - \frac{1}{\sqrt{x}}\right)$$

$$\frac{1}{\sqrt{x}} = \frac{1}{\sqrt{1.5}} + 0.5975$$

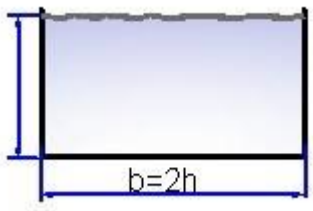
$$\frac{1}{\sqrt{x}} = 1.414$$

$$x = 0.50$$

$$Elev.\ of\ water\ surface = 64 + 0.5$$

$$Elev.\ of\ water\ surface = 64.5\,m.$$

For optimum dimension, determine the width of the rectangular channel with slope S = 0.0008 and n = 0.012 if the rate of flow is 4 m³/s.



Solution:

$$A = b\,h$$

$$b = 2\,h$$

$$A = 2h^2$$

$$R = \frac{h}{2}$$

$$Q = AV$$

$$Q = A\frac{1}{n}R^{2/3}\,S^{1/2}$$

$$4 = \frac{2h^2}{0.012}\left(h/2\right)^{2/3}\left(0.0008\right)^{1/2}$$

$$h^{8/3} = 1.347$$

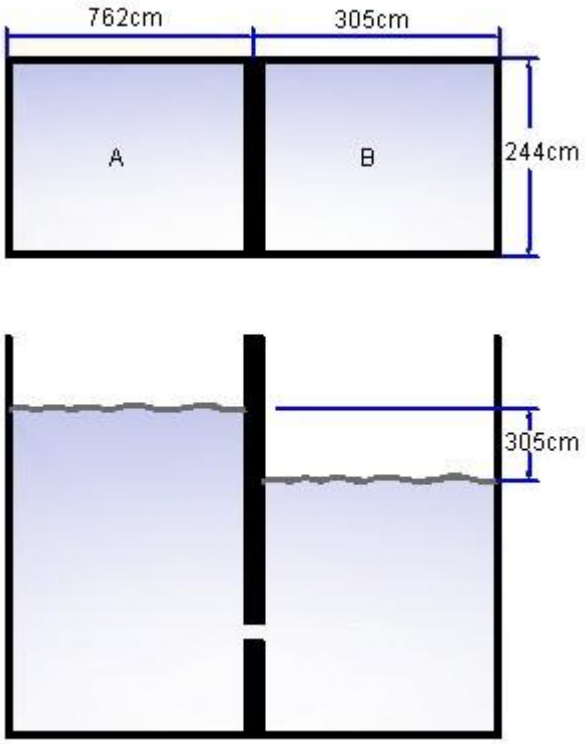
$$h = 1.12$$

$$b = 2h$$

$$b = 2\left(1.2\right)$$

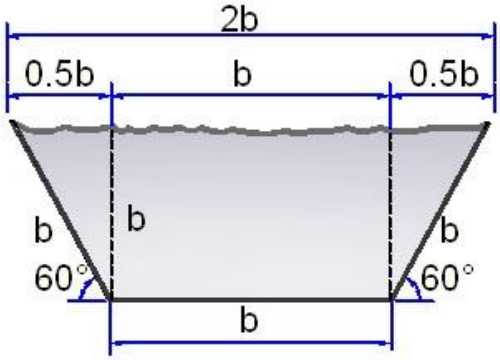
$$b = 2.24\ m.$$

A rectangular tank is divided by a partition into two chambers as shown. An orifice having a cross sectional area of 0.2 m² for which C = 0.93 is located near the bottom of the chamber. At a certain time, the water level in chamber A is 305 cm. higher than in chamber B. Find the time it will take for the water surfaces in the two chambers to be at the same level. Use the most nearest value.



Solution:

An open channel having a trapezoidal section is required to discharge 200 m³/sec. of water when running full. If the slope S = 0.002 and n = 0.014, compute the bottom width for a most efficient section.



Solution:

$$A_1 = 2.44(7.62)$$

$$A_1 = 18.59 m^2$$

$$A_2 = 2.44(3.05)$$

$$A_2 = 7.44 m^2$$

$$t = \frac{2A_1 A_2\left(\sqrt{h_1} - \sqrt{h_2}\right)}{\left(A_1 + A_2\right)CA\sqrt{2g}}$$

$$t = \frac{2(18.59)(7.44)\left(\sqrt{3.05} - \sqrt{0}\right)}{(18.59 + 7.44)(0.93)(0.2)\sqrt{2(9.81)}}$$

$t = 22.53$ sec.

$$Sin60° = \frac{d}{b}$$

$$d = b\,Sin60°$$

$$R = \frac{d}{2}$$

$$R = \frac{b\,Sin60°}{2}$$

$$R = 0.433b$$

$$A = \frac{(b + 2b)}{2}d$$

$$A = \frac{1}{2}(3d)(b)Sin60°$$

$$A = 1.299b^2$$

$$Q = AV$$

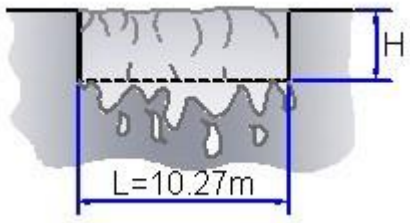
$$Q = A\frac{1}{n}R^{2/3}S^{1/2}$$

$$200 = \frac{1.299b^2}{0.014}(0.433b)^{2/3}(0.002)^{1/2}$$

$$b^{8/3} = 266.30$$

$b = 8.12$ m.

A rectangular weir contracted a both ends is 10.27 m. wide extends across a rectangular channel. Find the head of water for a discharge of $3m^3/sec$.



Solution:

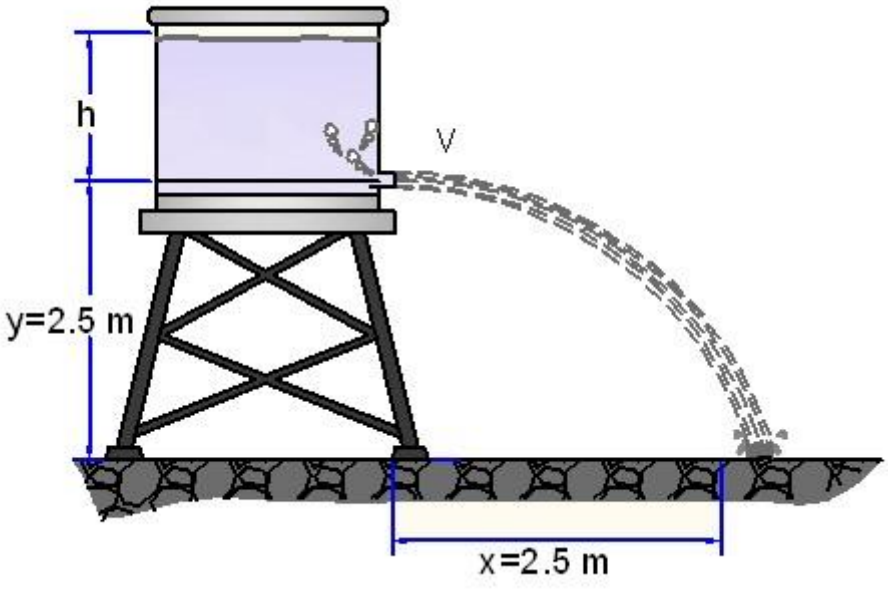
$$Q = 1.84(L - 0.2H)\, H^{3/2}$$

$$3 = 1.84\,[10.27 - 0.2H]\, H^{3/2}$$

$$1.63 = 10.27\, H^{3/2} - 0.2\, H^{5/2}$$

Try H = 0.295

A vessel has an orifice located in the vertical side of a cylindrical vessel under a head "h". The jet strikes a horizontal plane 2.5m. below the center of the orifice at a point 2.5m. measured horizontally from the vertical plane of the orifice. Determine the value of "h".



Solution:

$$y = \frac{1}{2} g t^2$$

$$1.5 = \frac{1}{2}(9.81)(t^2)$$

$$t = 0.71$$

$$2.5 = V(0.71)$$

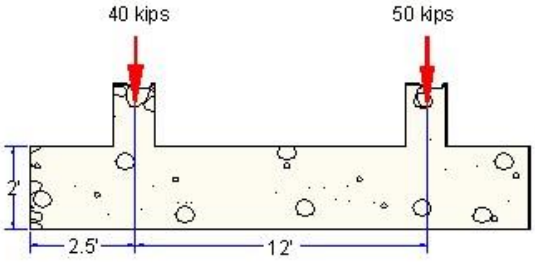
$$V = 3.52 m/s$$

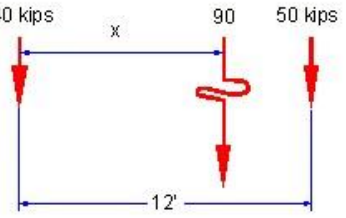
$$V = \sqrt{2gh}$$

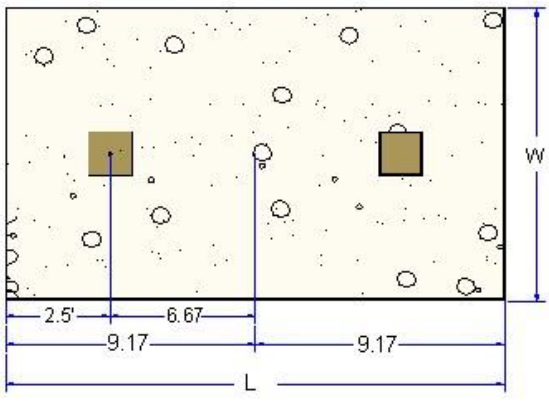
$$3.52 = \sqrt{2(9.81)h}$$

$$h = 0.63\ m.$$

The figure shows the column loads and the footing elevation. The depth of the pad is adequate and the DL of the footing maybe neglected. The columns are axially loaded only. Determine the dimension of the footing if the allowable soil pressure is 2000 psf.







Solution:

Locate the centroid of the axial loads.

90x = 50(12) + 40(0) x =6.67 ft.
The centroid of footing should coincide with the centroid of the loads

$$Area\ required = \frac{40000+50000}{2000}$$

$$A = 45 m^2$$

$$L = \left(6.67 + 2.5\right) 2$$

$$L = 18.34$$

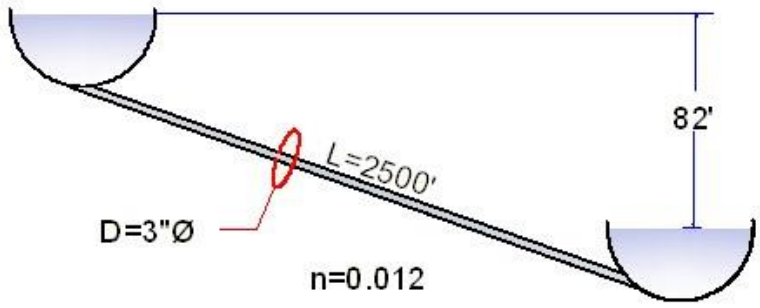
$$LW = A$$

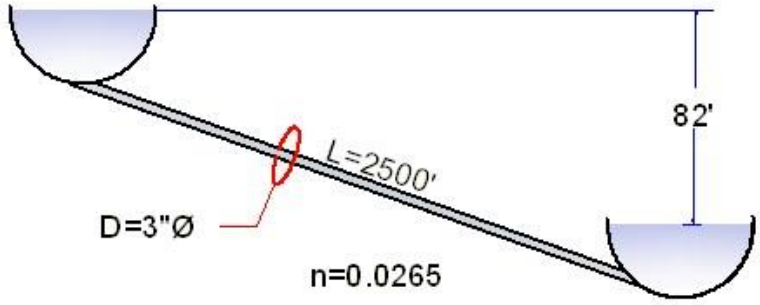
$$W = \frac{45}{18.34}$$

$$W = 2.45$$

$$Use\ 18.34' \times 2.45'$$

Tow reservoirs having a difference in elevation of 82 ft. is connected by a 3 inch diam. pipe, 2500 feet long with a roughness coefficient n = 0.012. After 10 years, the roughness coefficient n = 0.0265. Find the percentage change in discharge.





Solution:

$$hf = \frac{2.87\, n^2\, L\, V^2}{D^{4/3}}$$

$$82 = \frac{2.87\,(0.012)^2\,(2500)V_1^2}{(3/12)^{4/3}}$$

$$V_1 = 3.54\, fps$$

$$Q_1 = A_1 V_1$$

$$Q_1 = 0.174\, cfs$$

Ten years after:

$$82 = \frac{2.87\,(0.0265)^2\,(2500)V_2^2}{(3/12)^{4/3}}$$

$$V_2 = 1.60\ fps$$

$$Q_2 = A_2 V_2$$

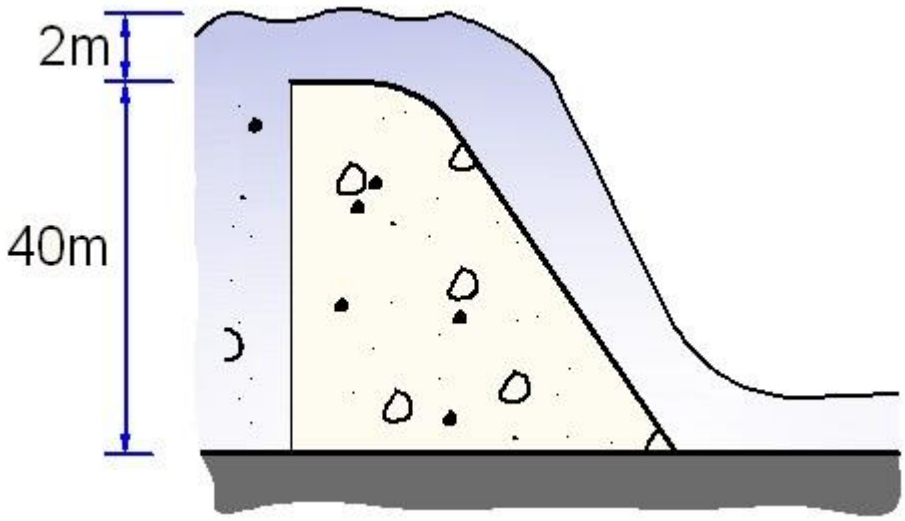
$$Q_2 = \frac{\pi}{4}\left(\frac{3}{12}\right)^2 (1.60)$$

$$Q_2 = 0.079\, cfs$$

$$\%\ change\ in\ Q = \frac{(0.174 - 0.079)}{0.174} x100$$

$$\%\ change\ in\ Q = 54.6\%$$

A spillway 2m. deep goes over a dam 40 m. high If C_w = 3.2, determine the discharge?



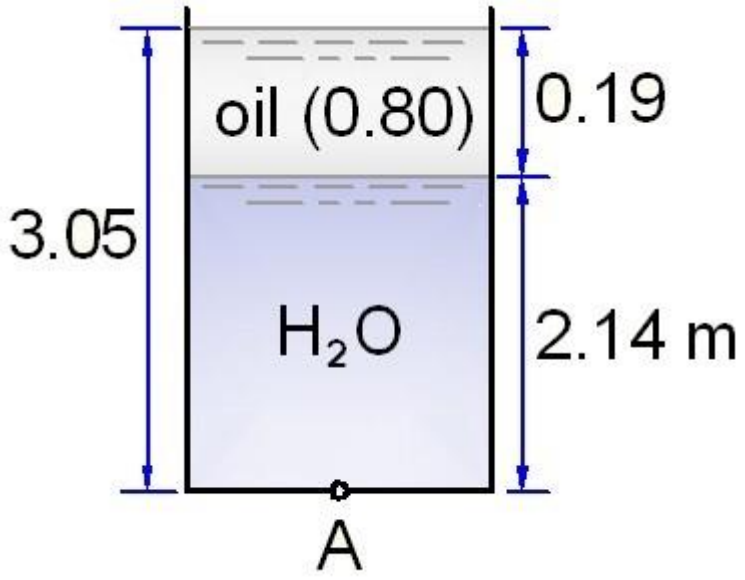
Solution:

$Q = C_w L H^{3/2}$

$Q = 3.2(1)(2)^{3/2}$

$Q = 9.05\ m^3/s/meter$

Oil with a specific gravity of 0.80 is 0.91 m. deep in an open tank which is otherwise filled with water. If the tank is 3.05 m. deep, what is the pressure at the bottom of the tank?

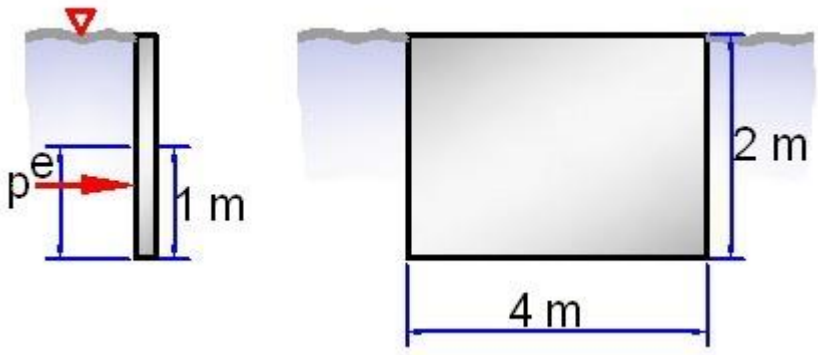


Solution:

P_A = 9.81(0.8)(0.91) + 9.81(2.14)

P_A = 28.14 kPa

A gate 2m. high and 4m. wide is flush with water at the top. Determine the moment at the bottom.



Solution:

$$P = whA$$

$$P = 9.81(1)(2)(4)$$

$$P = 78.48kN$$

$$e = \frac{\text{lg}}{Ss}$$

$$\text{lg} = \frac{4(2)^3}{12}$$

$$\text{lg} = 2.67$$

$$Ss = Ay$$

$$Ss = 4(2)(1)$$

$$Ss = 8$$

$$e = \frac{2.67}{8}$$

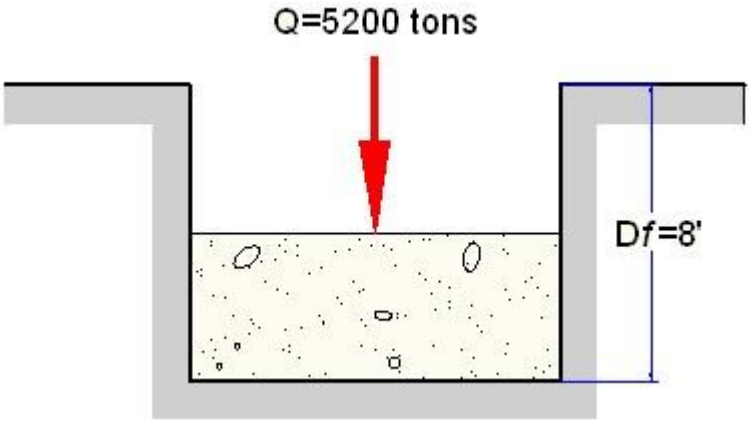
$$e = 0.333$$

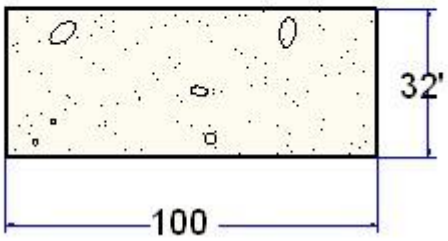
$$M = 78.48(1 - 0.333)$$

$$M = 52.35\ kN.m$$

A mat foundation having a length of 100ft. by 32ft. carries a total weight of structure plus live load of 5200 tons. The mat foundation is supported by sand underneath. Unit weight of sand is 120 pcf. The N value from the standard penetration test is equal to 18 with a correction factor C_n =
0.62. If the base of the footing is 8ft. below the ground level.

1) **Compute the overburden pressure 8ft. below the ground.**
2) **Compute the allowable net soil pressure.**
3) **Compute the factor of safety against bearing capacity failure.**


Q=5200 tons
Df=8'


32'
100

1 Overburden pressure:

$$P = \gamma D_f$$

$$P = \frac{120(8)}{2000}$$

$$P = 0.48\ tons/ft^2$$

2 Allowable net soil pressure

$$= 0.22N$$

$$= 0.22(18)$$

$$= 3.96\ tons/ft^2$$

3 Factor of safety against bearing capacity failure:

$$Net\ soil\ pressure = \frac{Q}{A} - \gamma D_f$$

$$Net\ soil\ pressure = \frac{5200}{100(32)} - \frac{120(8)}{2000}$$

$$Net\ soil\ pressure = 1.145\ tons/ft^2$$

Note:

Because the differential settlement of a mat foundation are less than those of an individual footing foundation designed for the same soil pressure, it is reasonable soil pressures on mat foundations. Experience has shown that a pressure approximately 2 times as great as that allowed for individual footings maybe used

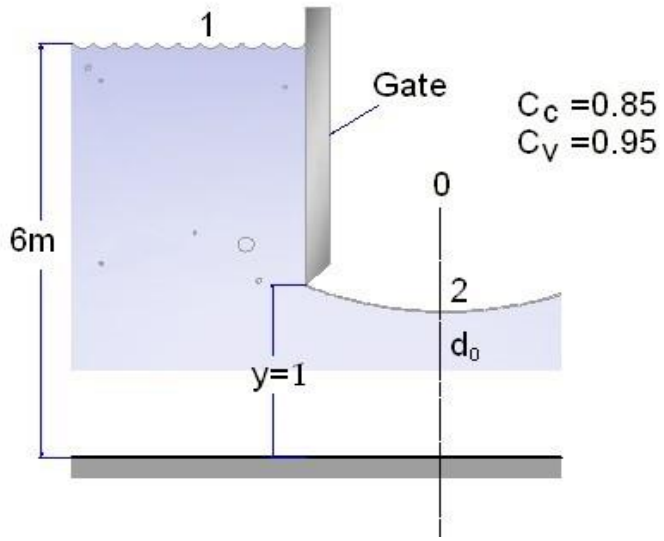
$$F.S. = \frac{2\ allowable\ net\ pressure}{Net\ soil\ pressure}$$

$$F.S. = \frac{2(3.96)}{1.145}$$

$$F.S. = 6.92$$

because it does not lead to detrimental differential settlements.

A dam gate in the figure shown admits water to a horizontal canal. Considering the pressure distribution hydrostatic at section O, compute the discharge per meter of width when y = 1.0 m.



Solution:

$$d_o = C_c\, y$$

$$d_o = 0.85(1.0)$$

$$d_o = 0.85m.$$

$$\frac{V_1^2}{2g} + \frac{P_1}{\gamma} + Z_1 = \frac{V_2^2}{2g} + \frac{P_2}{\gamma} + Z_2 + H\,L$$

$$0 + 0 + 6 = \frac{V_2^2}{2g} + 0 + 0.85 + 0$$

$$V_1 = V_2 = 10.05\ m/s$$

$$V = C_v\, V_t$$

$$V = 0.95(10.05)$$

$$V = 9.548\ m/s$$

Consider 1m width :

$$Q = AV$$

$$Q = 0.85(1)(9.548)$$

$$Q = 8.12\ m^3/s$$

$$P = 0.63(9.81)(18)$$

$$P = 111.24\ kW$$

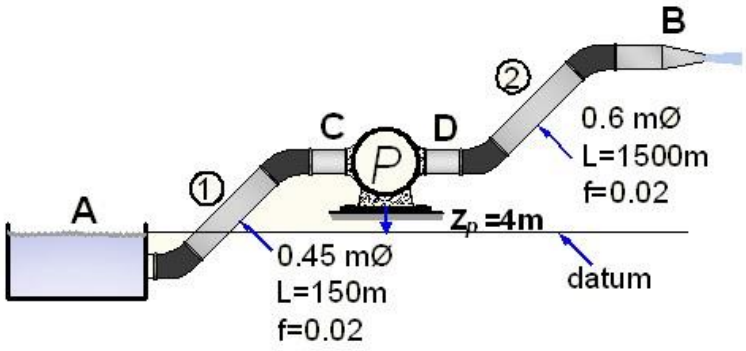
In the figure shown Z_p = 4m., length of pipe from reservoir to pump is 150m., from pump to nozzle is 1500m., f = 0.02 and diameter of pipes are 450mm and 600mm respectively. Neglecting minor losses the water maybe pumped if the atmospheric pressure is 95kPa absolute and the water temperature is 27°C. At this temperature the vapor pressure P_v =
3.5kPa absolute.

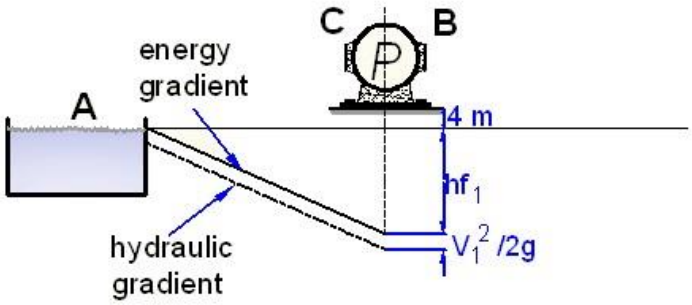
Determine:

1) **Velocity of water in 450mmØ pipe.**

2) **The velocity of water in 600mmØ pipe.**

3) **The power lost due to friction.**





Solution:

Note: If the absolute pressure at any point in a system falls to the vapor pressure P_v, water vapor and dissolved gasses will collect in high spots and obstruct the flow. The lowest pressure in the system occurs at point
C on the suction side of the pump and flow would stop when

$$\frac{P_c}{\gamma} = -\left(\frac{P_{atm} - P_v}{\gamma}\right)$$

[1] Velocity in the 450 mmϕ pipe:

$$\frac{P_c}{\gamma} = -\frac{\left(P_{atm} - P_v\right)}{\gamma}$$

$$\frac{P_c}{\gamma} = -\frac{(95 - 3.5)}{9.81} = -9.33 \quad (1)$$

$$\frac{P_c}{\gamma} = -\left(4 + \frac{fLV_1^2}{D2g} + \frac{V_1^2}{2g}\right)$$

$$\frac{P_c}{\gamma} = -\left(4 + \frac{0.02(150)V_1^2}{0.45(2)(9.81)} + \frac{V_1^2}{2(9.81)}\right)$$

$$\frac{P_c}{\gamma} = -\left(4 + \frac{6.67V_1^2}{2g}\right) - (2)$$

$$9.33 = 4 + \frac{6.67V_1^2}{2g}$$

$V_1 = 3.96\ m/s$

[2] Velocity in the 600 mmϕ pipe:

$Q_1 = Q_2$

$A_1V_1 = A_2V_2$

$$\frac{\pi}{4}(0.45)^2\,3.96 = \frac{\pi}{4}(0.6)^2 V_2$$

$V_2 = 2.23\ m/s$

[3] Power lost due to friction

$H_L = hf_1 + hf_2$

$$H_L = \frac{fL_1V_1^2}{D_1 2g} + \frac{fL_2V_2^2}{D_2 2g}$$

$$H_L = \frac{0.02(150)(3.96)^2}{(0.45)2(9.81)} + \frac{0.02(1500)(2.23)^2}{(0.6)2(9.81)}$$

$H_L = 18m.$

$Q = AV$

$$Q = \frac{\pi}{4}(0.45)^2\,3.96$$

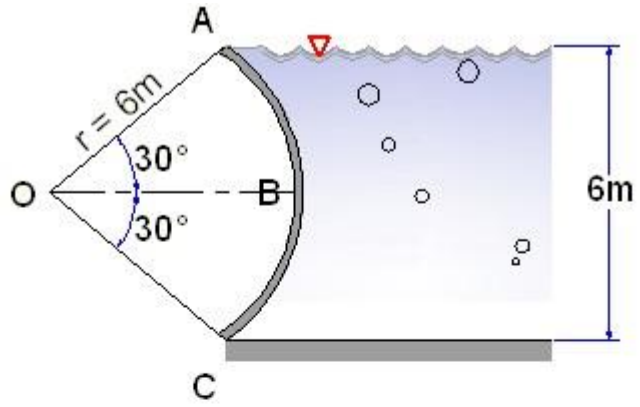
$Q = 0.63\ m^3/s$

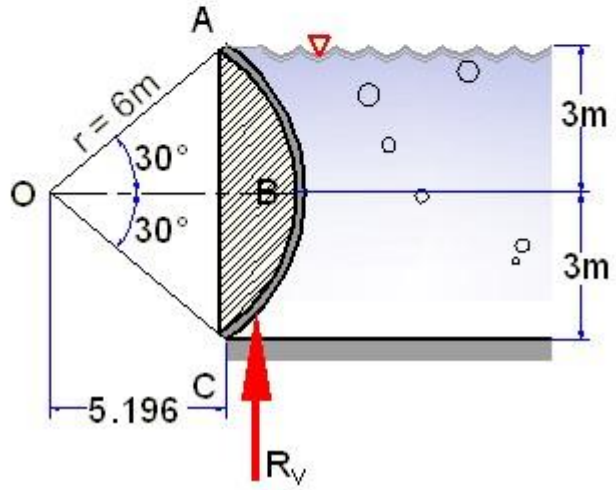
$P = Q\gamma E$

$P = 0.63(9.81)(18)$

$P = 111.24\ kW$

Curve wall ABC is a quarter circle having a radius of 6m. What is the vertical force acting on the gate per unit width.





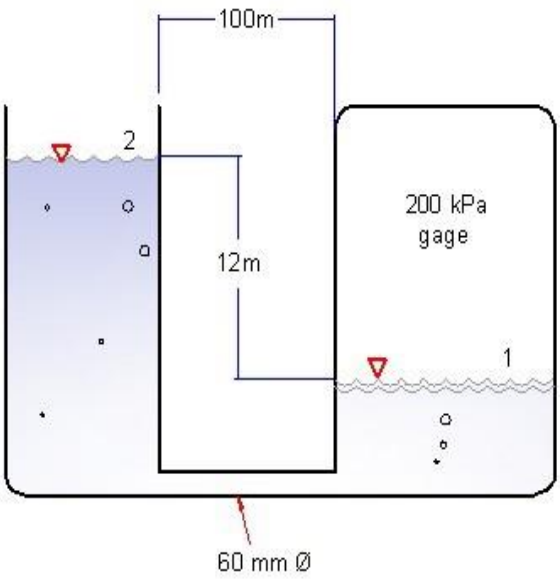
Solution:

$$R_v = \left[\frac{\pi(6)^2(60)^\circ}{360^\circ} - \frac{3(5.196)(2)}{2}\right]9.81$$

$$R_v = 32\,kN$$

The 100 duct is 60mm in diameter. If the fluid has ρ = 920kg/m³ and a viscosity of μ = 0.29 Pa.s.

1) **Compute the velocity of flow on the duct.**
2) **Compute the Reynolds Number3) Compute the discharge.**



1 Discharge of flow:

$$\frac{V_1^2}{2g}+\frac{P_1}{w}+Z_1=\frac{V_2^2}{2g}+\frac{P_2}{w}+Z_2+H_L$$

$$H_L=\frac{128\mu LQ}{\pi\rho g D^4}$$

$$H_L=\frac{128(0.29)(100)Q}{\pi(920)(9.81)(0.06)^4}$$

$$H_L=10102Q$$

$$0+\frac{200(1000)}{920(9.81)}+0=0+0+12+10102Q$$

$$Q=0.00219\ m^3/s$$

$$Q=7.897\ m^3/hour$$

2 Velocity of flow:

$$V=\frac{Q}{A}=\frac{0.00219}{\frac{\pi}{4}(0.06)^2}$$

$$V=0.7746\ m/s$$

3 Reynolds No.:

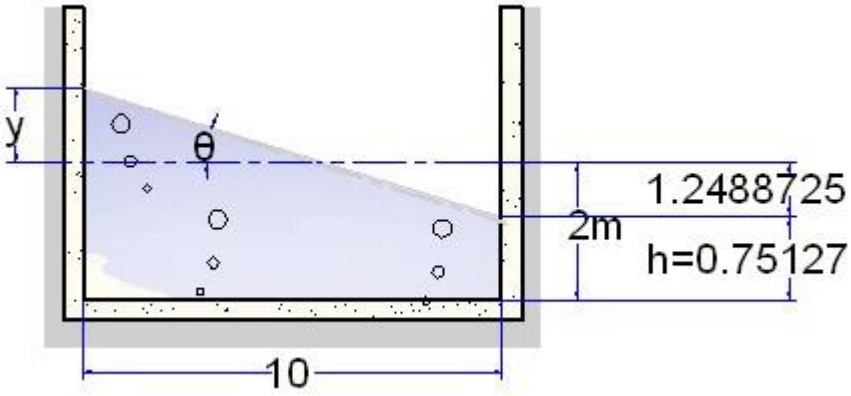
$$RE=\frac{\rho DV}{\mu}$$

$$RE=\frac{920(0.06)(0.7746)}{0.29}$$

$$RE=147.44$$

A tank 10m. is filled with 2m. of water is accelerated horizontally 2.45 m/s². What is the minimum pressure acting at the bottom of the tank?

Assume the tank is high enough to prevent spilling.



$$\tan\theta = \frac{a}{g}$$

$$\tan\theta = \frac{2.45}{9.81}$$

$$\tan\theta = 0.249745$$

$$\frac{y}{5} = 0.249745$$

$$y = 1.248725$$

$$h = 2 - 1.248725$$

$$h = 0.75127$$

$$P = \gamma_w h$$

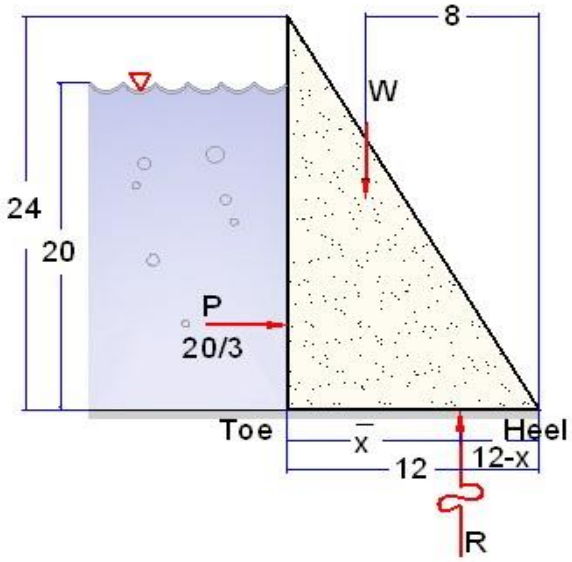
$$P = 9.81(0.75127)$$

$$P = 7.37\,kN/m^2$$

$$P = 7370\,N/m^2$$

Solution:

A dam triangular in shape has a height of 24m. and a base of 12m. Density of masonry is 2,500 kg/cu.m. If it is supporting was at a depth of 20m. Where is the location of the resultant vertical force from the heel office dam.



Solution:

$$W = \frac{34(12)}{2}(1)(2500)$$

$$W = 360,000\ kg$$

$$P = \gamma_w\, h\, A$$

$$P = 1000(10)(20)(1)$$

$$P = 200,000$$

$$R = W = 360,000$$

$$OM = \frac{P(20)}{3}$$

$$OM = \frac{200000(20)}{3}$$

$$OM = 1,333,333.33$$

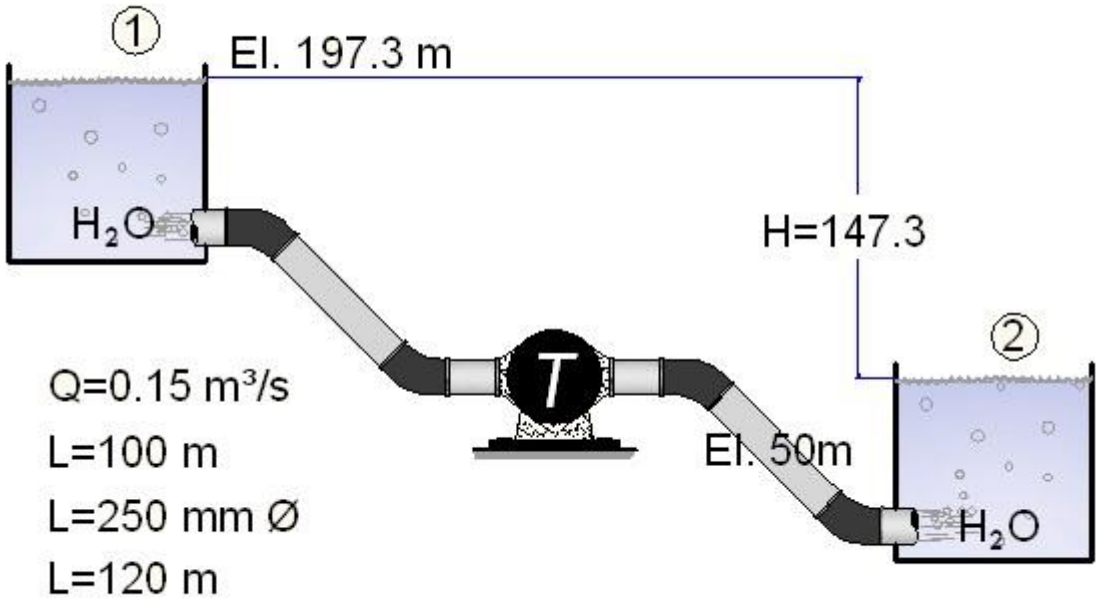
$$RM = 360,000(8)$$

$$RM = 2880000$$

Water flows from an upper reservoir to a lower one while passing through a turbine as shown. Neglect minor losses.

1) **Find the velocity of water**
2) **Find the head loss due to friction3) Find the**

   power generated by the turbine.



Solution:

$$Q = AV \qquad \boxed{1}$$

$$0.15 = \frac{\pi}{4}(0.25)^2 V$$

$$V = 3.06\ m/s$$

$$HL = \frac{10.64\, L\, Q^{1.85}}{C^{1.85} D^{4.87}} \qquad \boxed{2}$$

$$HL = \frac{10.64(100)(0.15)^{1.85}}{(120)^{1.85}(0.25)^{4.87}}$$

$$HL = 3.87\ m.$$

$$\frac{V_1^2}{2g} + \frac{P_1}{\gamma} + Z_1 - HE = \frac{V_2^2}{2g} + \frac{P_2}{\gamma} + Z_2 + HL \qquad \boxed{3}$$

$$0 + 0 + 147.3 - HE = 0 + 0 + 0 + HL$$

$$HE = 147.3 - 3.87$$

$$HE = 143.43m.$$

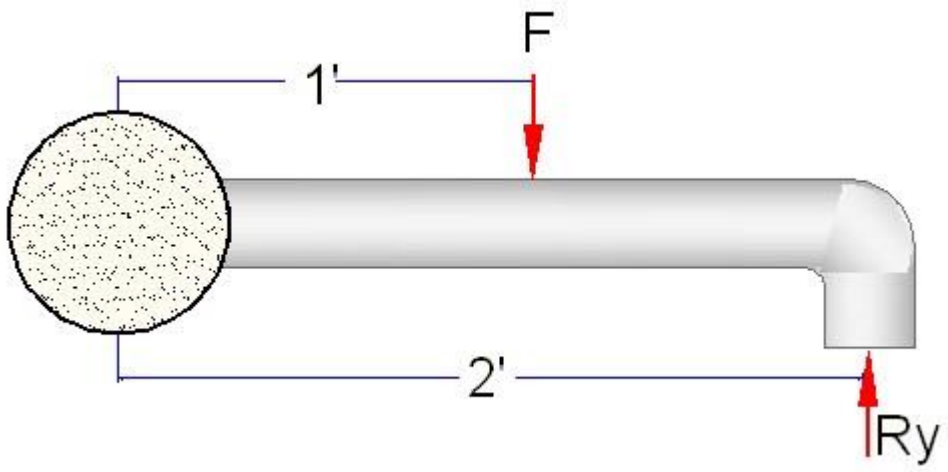
$$P = Q\gamma E$$

$$P = 0.15(9.79)(143.43)$$

$$P = 211kW$$

The jets from a garden sprinkler are one inch in diameter and are normal to the 2ft. radius The pressure at the base of the nozzles is 60 psi. Use $C_v = 0.85$, $C_c = 1.0$.

1) **What is the velocity of the jet?**
2) **What is the force exerted by the jet?**
3) **What force must be applied on each sprinkler pipe 1 ft. from the center of rotation to maintain equilibrium.**



Solution:

$$h = \frac{P}{\gamma} \qquad \boxed{1}$$

$$h = \frac{60(144)}{62.4}$$

$$h = 138.46\ ft.$$

$$V = C_v \sqrt{2g\,h}$$

$$V = 0.85\sqrt{2(32.2)138.46}$$

$$V = 80.26\ fps.$$

$$R_y = \frac{Q\gamma}{g} V \qquad \boxed{2}$$

$$Q = AV$$

$$Q = \frac{\pi}{4}\left(\frac{1}{12}\right)^2 (80.26)$$

$$Q = 0.438\ cfs$$

$$R_y = \frac{0.438(62.4)}{32.2}(80.26)$$

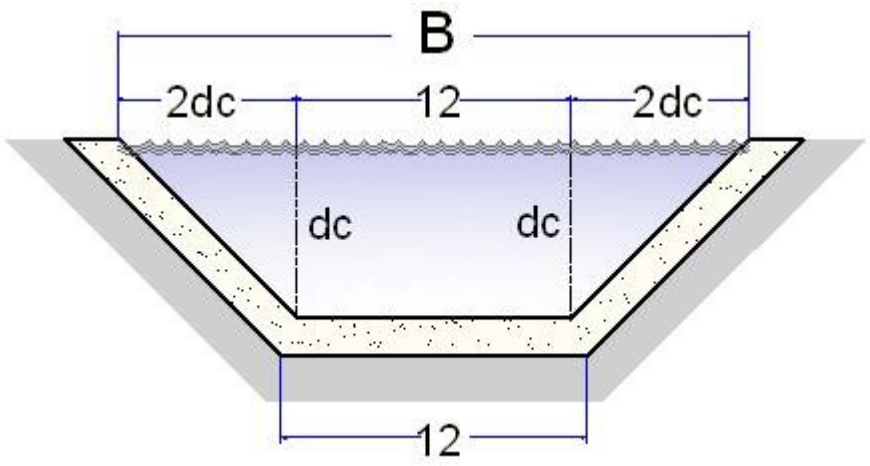
$$R_y = 68.12\ lb.$$

$$\sum M_0 = 0 \qquad \boxed{3}$$

$$68.12(2) = F(1)$$

$$F = 136.24\ lb.$$

What is the critical depth of a trapezoidal canal for a flow of 2300 cfs. The width at the bottom of the canal is 12ft. with a side slope of 2 horizontal to 1 vertical.



Solution:

$$A = \frac{\left(12 + 4d_c + 12\right)}{2} d_c$$

$$A = \left(2d_c + 12\right) d_c$$

$$B = 4d_c + 12$$

$$Q = 2300 cfs.$$

$$\frac{Q^2}{g} = \frac{A^3}{B}$$

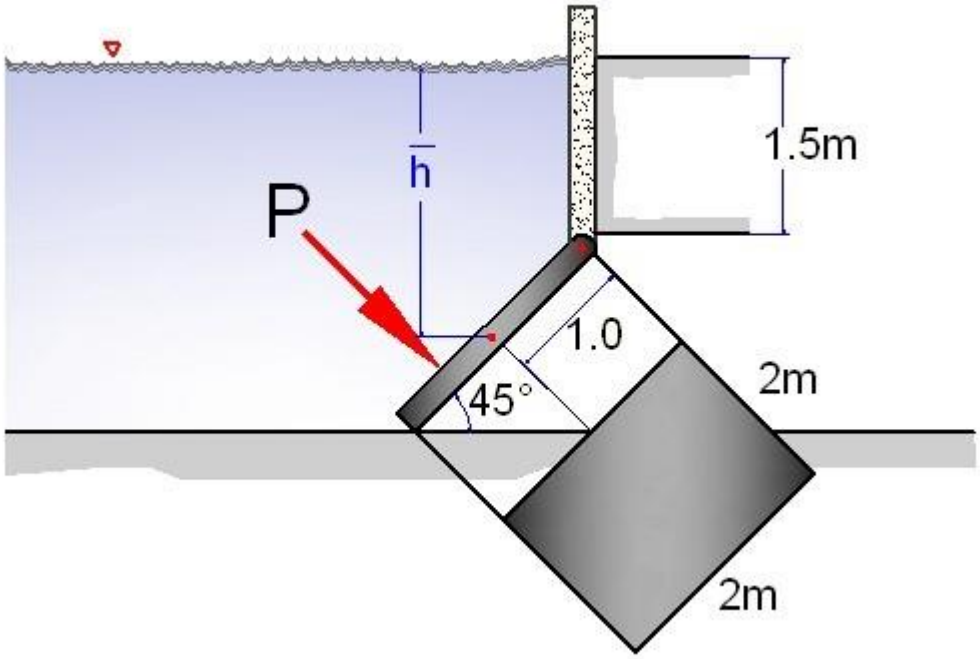
$$\frac{(2300)^2}{32.2} = \frac{\left(2{d_c}^2 + 12d_c\right)^3}{4d_c + 12}$$

$$164285.7 = \frac{\left(2{d_c}^2 + 12d_c\right)^3}{4d_c + 12}$$

$$Try\ d_c = 7.16$$

$$Use\ d_c = 7.16\ ft.$$

Find the total hydrostatic force acting on the gate shown.



Solution:

$\bar{h} = 1.5 + 1(Sin45°)$

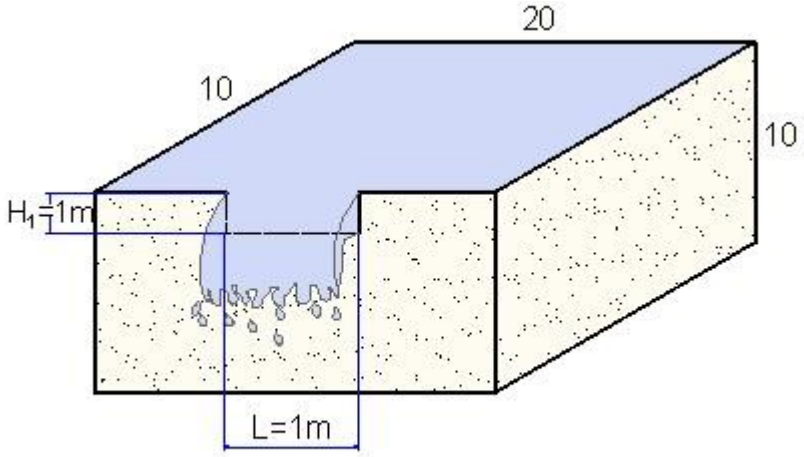
$\bar{h} = 2.21$

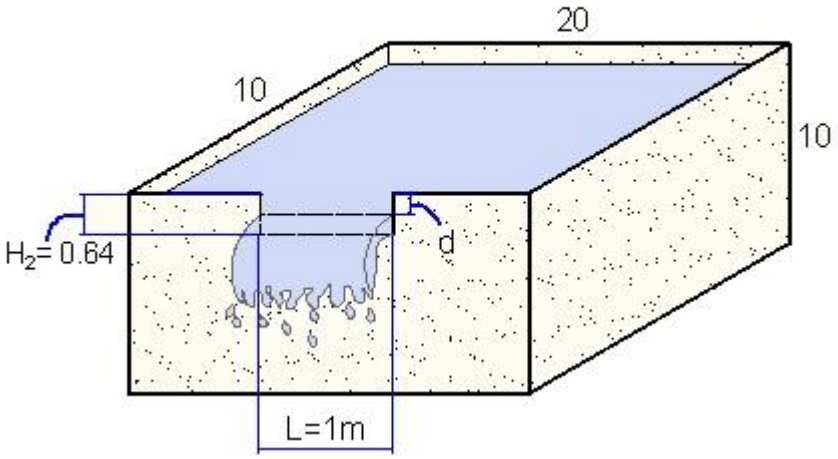
$P = \gamma h A$

$P = 9.81(2.21)(2)(2)$

$P = 86.72\,kN$

A rectangular weir having a length of one meter is constructed at one end of a tank having a square section 20×20m. and a height to 10m. If the initial head on the weir is 1m., determine the time required to discharge a volume of 72m³.





Solution:

$$Vol. = Ad$$

$$20(20)d = 72$$

$$d = 0.18$$

$$H_2 = 1 - 0.18$$

$$H_2 = 0.82$$

$$t = \frac{Vol.}{Q_{ave}}$$

Using Francis Formula

$$Q = 1.84\, L' H^{3/2}$$

$$Q = 1.84\left(L - 0.2H\right)H^{3/2}$$

When $H_1 = 1$ m.

$$Q_1 = 1.84\left[1 - 0.20(1)\right](1)^{3/2}$$

$$Q_1 = 1.472\ m^3/s$$

When $H_2 = 0.82$

$$Q_2 = 1.84\left[1 - 0.20(0.82)\right](0.82)^{3/2}$$

$$Q_2 = 1.142\ m^3/s$$

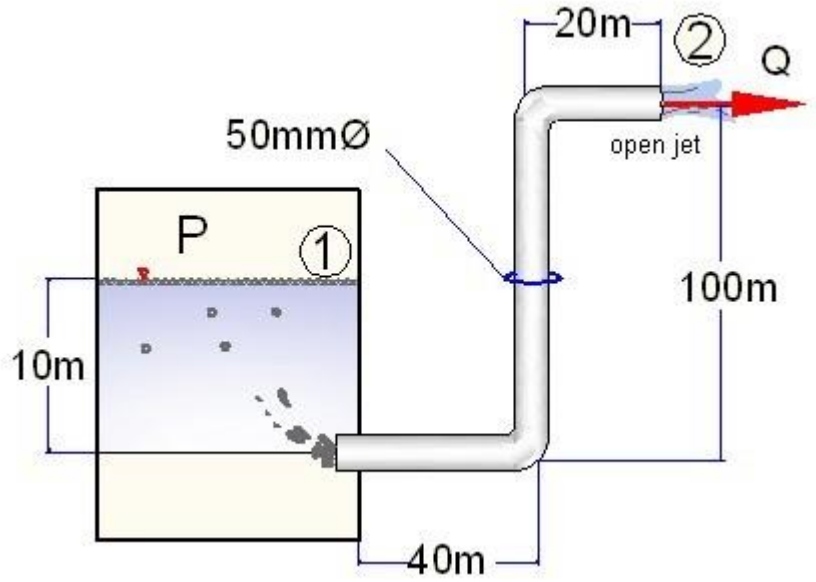
$$t = \frac{Vol.}{Q_{ave}}$$

$$t = \frac{72}{\frac{1.472 + 1.142}{2}}$$

$t = 55$ sec.

The pipe flow in the figure is driven by pressurized air in the tank. Assuming f = 0.014 and the flow rate is 13.60 liters/sec.

1) **Find the velocity of the water in the pipe.**
2) **Find the head loss in the pipe neglecting minor losses.**
3) **Find the gage pressure needed to provide a flow rate of 13.60 liters/sec.**



Solution:

1 Velocity of water in the pipe:

$$Q = AV$$

$$0.0136 = \frac{\pi}{4}(0.05)^2 V$$

$$V = 6.93\ m/s$$

2 Head loss in the pipe:

$$hf = \frac{fLV^2}{D2g}$$

$$hf = \frac{0.014(160)(6.93)^2}{0.05(2)(9.81)}$$

$$hf = 109.66\ m.$$

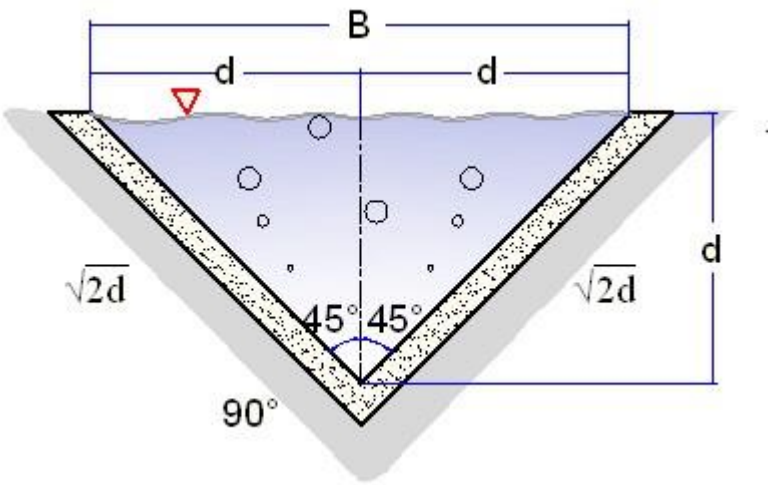
3 Gage pressure needed to provide a flow of 13.60liters/sec.

$$\frac{V_1^2}{2g} + \frac{P_1}{w} + Z_1 = \frac{V_2^2}{2g} + \frac{P_2}{w} + Z_2 + HL$$

$$0 + \frac{P_1}{w} + 10 = \frac{(6.93)^2}{2(9.81)} + 0 + 100 + 109.66$$

$$P_1 = 1982.69\ kPa$$

An open channel having a slope of 0.0065 is to carry 1.0 m^3/s. The channel material has a "n" value of 0.011. Find the depth of the most efficient cross section for a triangular section.



Solution:

$$A = \frac{2d\,d}{2}$$

$$A = d^2$$

$$P = 2\sqrt{2}\,d$$

$$R = \frac{A}{P}$$

$$R = \frac{d^2}{2\sqrt{2}\,d}$$

$$R = 0.354d$$

$$Q = AV$$

$$1.0 = d^2 \frac{1}{0.011}(0.354d)^{2/3}(0.0065)^{1/2}$$

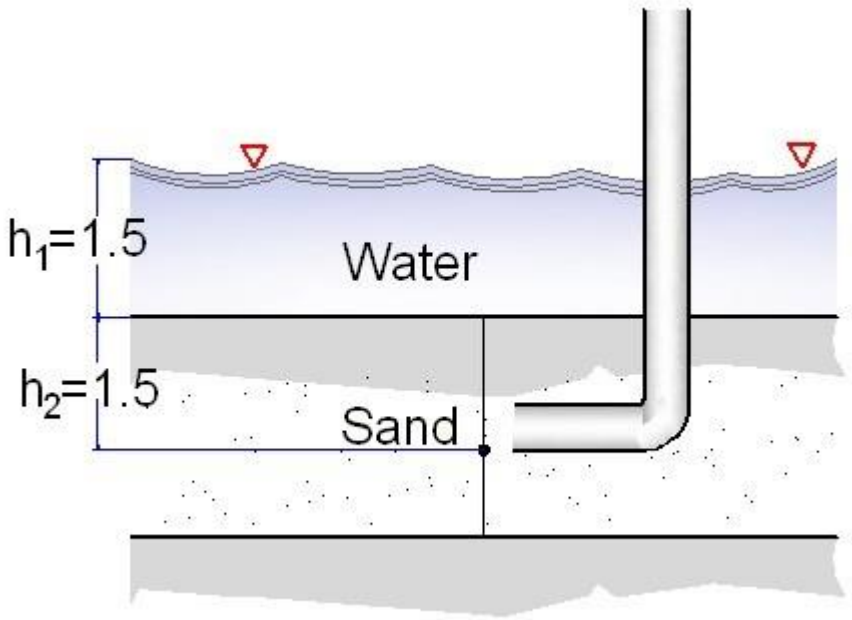
$$d^{8/3} = 0.273$$

$$d = 0.614m.$$

$$d = 614\,mm\ (depth)$$

For the given soil: void ratio, e = 0.50, Gs = 2.70, h_1 = 1.5m., h_2 = 3.0m.

1) **Which of the following gives the effective unit weight of soil.**
2) **Which of the following gives the effective stress at A**
3) **Which of the following gives the hydraulic gradient for quick sand condition.**



Solution:

1) **Effective unit weight of soil**

$$\gamma_{sat} = \frac{(G_s + e)\gamma_w}{1+e}$$

$$\gamma_{sat} = \frac{(2.70+0.50)9.81}{1+0.50}$$

$$\gamma_{sat} = 20.93\ kN/m^3$$

$$Effective\ unit\ weight = \gamma_{sub}$$

$$\gamma_{sub} = \gamma_{sat} - \gamma_w$$

$$\gamma_{sub} = 20.93 - 9.81$$

$$\gamma_{sub} = 11.12 kN/m^3$$

2) **Effective stress at A:**

Effective stress at A = 11.12(3)

Effective stress at A = 33.36 kN/m²

3) **Hydraulic gradient for quick sand condition**

$$i_{or} = \frac{G_s - 1}{1+e}$$

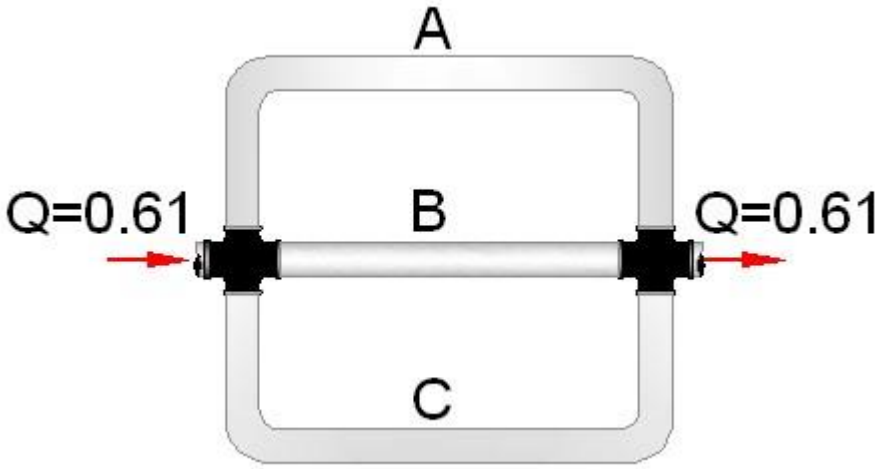
$$i_{or} = \frac{2.70-1}{1+0.50}$$

$$i_{or} = 1.13$$

Three pipes A, B and C are connected in parallel. If the combined discharged of the 3 pipes is equal to 0.61 m^3/s, and assuming they have equal values of friction factor "f", compute the following using the tabulated data shown.

PIPELINE	LENGTH	DIAM.
A	600 m.	150 m.
B	480 m.	200 m.
A	750 m.	100 m.

1) **Compute the rate of flow of pipeline A in li/sec.**
2) **Compute the rate of flow of pipeline B in li/sec.**
3) **Compute the rate of flow of pipeline C in li/sec.**



Solution:

1 Rate of flow of pipeline A :

$$hf_A = hf_B = hf_C$$

$$\frac{0.0826 f L_A Q_A^2}{(D_A)^5} = \frac{0.0826 f L_B Q_B^2}{(D_B)^5}$$

$$\frac{600 Q_A^2}{(0.15)^5} = \frac{480 Q_B^2}{(0.2)^5}$$

$$Q_A = 0.436 Q_B$$

$$Q_B = 2.295 Q_A$$

$$\frac{600 Q_A^2}{(0.15)^5} = \frac{750 Q_C^2}{(0.10)^5}$$

$$Q_A = 0.436 Q_C$$

$$Q_C = 2.295 Q_A$$

$$Q_A + Q_B + Q_C = 0.61$$

$$Q_A + 2.295 Q_A + 0.325 Q_A = 0.61$$

$$Q_A = 0.17 m^3/s$$

$$Q_A = 170 \, liters/\text{sec.}$$

2 Rate of flow of pipeline B :

$$Q_B = 2.295 Q_A$$

$$Q_B = 2.295(0.17)$$

$$Q_B = 0.39 m^3/s$$

$$Q_B = 390 \, liters/\text{sec.}$$

3 Rate of flow of pipeline C :

$$Q_C = 0.325 Q_A$$

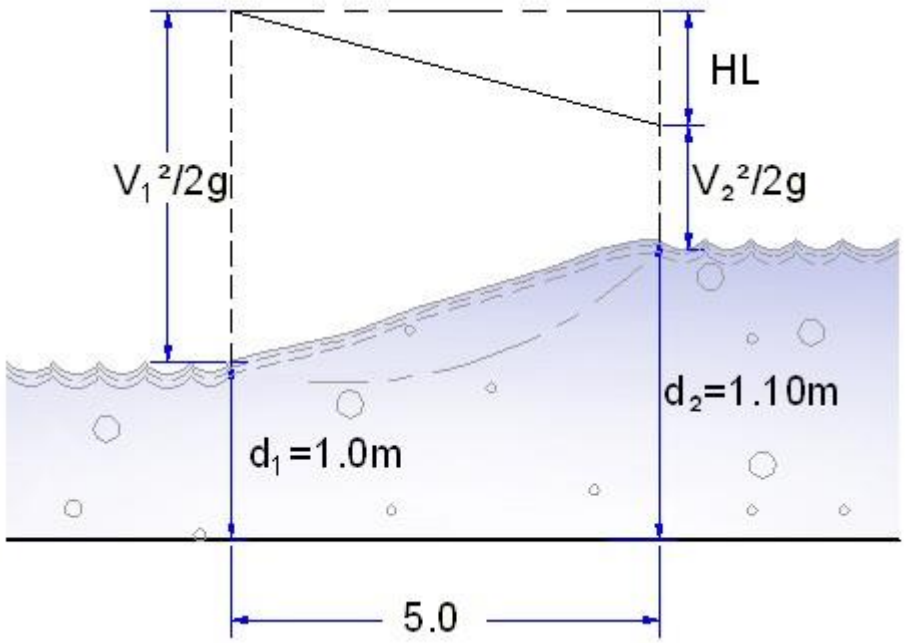
$$Q_C = 0.325 (0.17)$$

Water flows through an almost level channel 30m. wide at 12 m^3/s. The depth gradually increases form 1.0m. to 1.1m. for a length of flow of 5m.

1) **What is the head loss?**

2) **What is the slope of the energy gradient.**

3) **Compute the value of the roughness coefficient.**



Solution:

1 Head loss :

$$\frac{V_1^2}{2g} + d_1 = \frac{V_2^2}{2g} + d_2 + HL$$

$$V_1 = \frac{Q}{A_1}$$

$$V_1 = \frac{12}{3(1)}$$

$$V_1 = 4 m/s$$

$$V_2 = \frac{Q}{A_2}$$

$$V_2 = \frac{12}{3(1.1)}$$

$$V_2 = 3.64 m/s$$

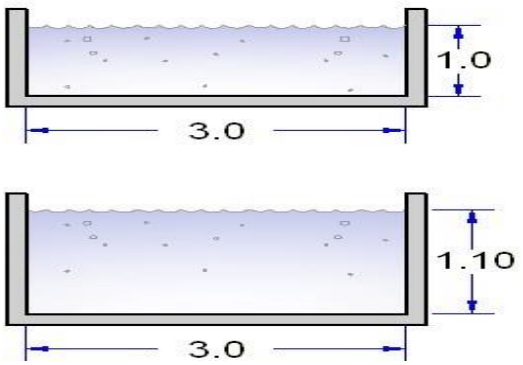
$$\frac{(4)^2}{2(9.81)} + 1.0 = \frac{(3.64)^2}{2(9.81)} + 1.1 + HL$$

$$HL = 0.04$$

2 Slope of energy gradient :

$$S = \frac{0.04}{5}$$

$$S = 0.008$$



3 Roughness coefficient :

$$A_1 = 3(1) = 3$$

$$P_1 = 3+1+1 = 5$$

$$R_1 = \frac{A_1}{P_1}$$

$$R_1 = \frac{3}{5}0.6$$

$$V_m = \frac{V_1 + V_2}{2}$$

$$V_m = \frac{4+3.64}{2}$$

$$V_m = 3.82 m/s$$

$$A_2 = 3(1.1) = 3.3$$

$$P_2 = 3+1.1+1.1 = 5.2$$

$$R_2 = \frac{A_2}{P_2}$$

$$R_2 = \frac{3.3}{5.2}$$

$$R_2 = 0.635$$

$$R_m = \frac{R_1 + R_2}{2}$$

$$R_m = \frac{0.6+0.635}{2}$$

$$R_m = 0.6175$$

$$V_m = \frac{1}{n} R_m^{2/3} S^{1/2}$$

$$3.82 = \frac{(0.6175)^{2/3} (0.008)^{1/2}}{n}$$

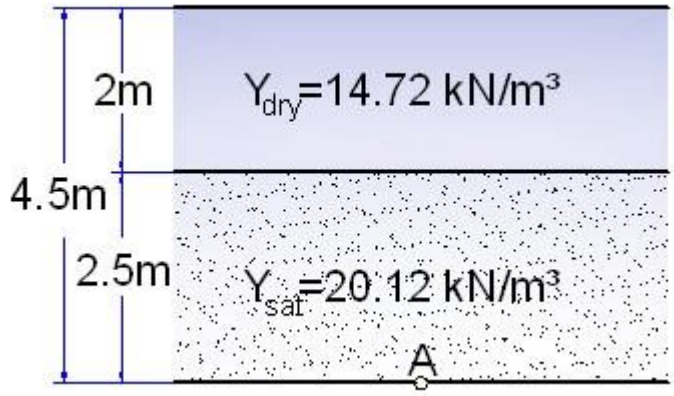
$n = 0.017$

A given layer of soil has a dry unit weight of 14.72 kN/m³ and a saturated unit weight of 20.12 kN/m³. The ground water table is located 2m. below the ground surface.

1) **What is the total stress at point A 4.5 m. below the ground surface.**

2) **What is the pore pressure at point A 4.5 m. below the ground surface.**

3) **What is the effective stress at point A 4.5 m. below the ground surface.**



1 Total stress at point A :

$$\textit{Total stress at point } A$$

$$= 2(14.72) + 20.12(2.5)$$

$$= 79.74\ kPa$$

2 Pore pressure at A :

$$\textit{Pore pressure at } A = 9.81(2.5)$$

$$\textit{Pore pressure at } A = 24.53\ kPa$$

3 Effective stress at A :

$$\textit{Effective stress at } A = 79.74 - 24.53$$

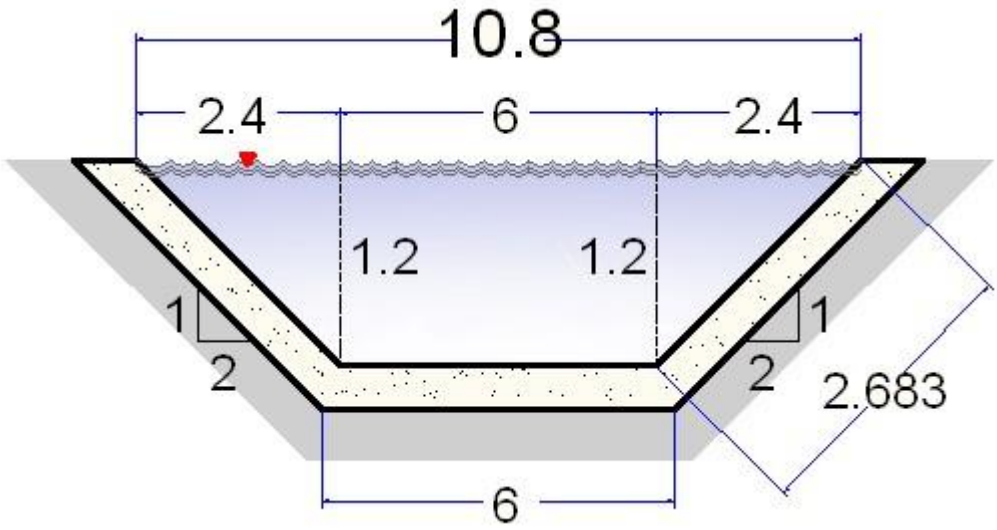
$$\textit{Effective stress at } A = 55.21\ kPa$$

A trapezoidal channel has a bottom width of 6m. and side slopes of 2 hor. to 1 vertical. When the depth of flow is 1.2m., the flow is 20.40 m^3/s.

1) **Compute the specific energy.**

2) **Compute the slope of channel if n = 0.014.**

3) **Compute the average shearing stress at the boundary.**



Solution:

1 Specific energy :

$$A = \frac{(10.8+6)}{2}(1.2)$$

$$A = 10.08\ m^2$$

$$Q = AV$$

$$20.40 = 10.08V$$

$$Specific\ energy = \frac{V^2}{2g} + d$$

$$E = \frac{(2.02)^2}{2(9.81)} + 1.2$$

$$E = 1.41\ \ m.$$

2 Slope of channel :

$$V = \frac{1}{n} R^{2/3} S^{1/2}$$

$$P = 2.683(2) + 6$$

$$P = 11.366$$

$$R = \frac{A}{P}$$

$$R = \frac{10.08}{11.36}$$

$$R = 0.887$$

$$2.02 = \frac{(0.887)^{2/3} S^{1/2}}{0.014}$$

$$S = 0.00094$$

3 Ave shearing stress :

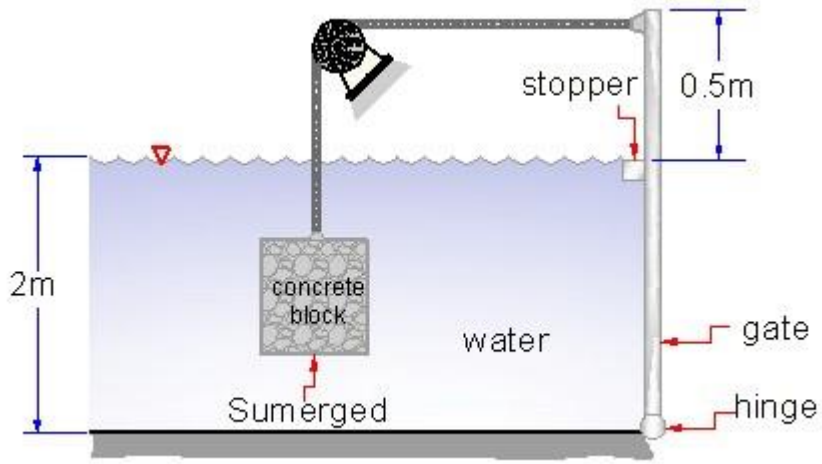
$$\tau = \gamma_w R S$$

$$\tau = 9.81(0.887)(0.00094)$$

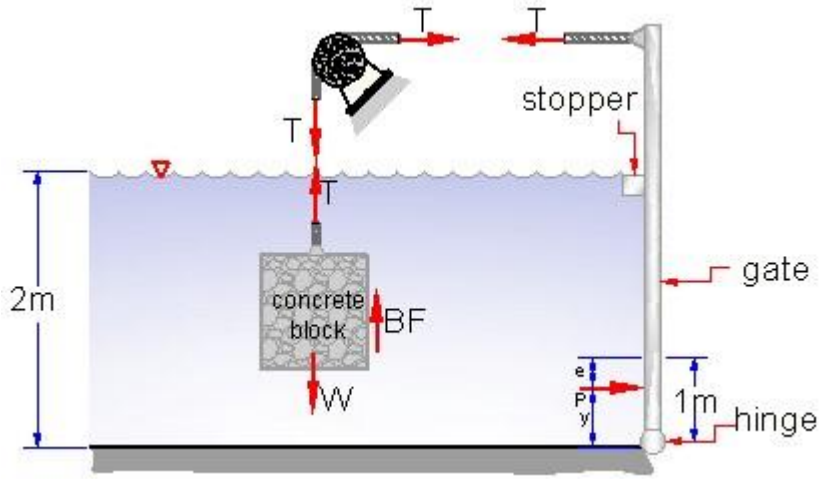
$$\tau = 0.0082\ kPa$$

From the figure shown, the gate is 1m. wide and is hinged at the bottom of the gate.

1) **Compute the hydrostatic force acting on the gate.**
2) **Compute the location of the center of pressure of the gate from the hinged.**
3) **Determine the minimum volume of concrete (unit weight = 23.6 kN/m³) needed to keep the gate in a closed position.**



Solution:



1 Hydrostatic force :

$$P = \gamma_w \bar{h} A$$

$$P = 9.81(1)(2)(1)$$

$$P = 19.62\,kN$$

2 Location of center of pressure :

$$e = \frac{Ig}{Ss}$$

$$e = \frac{(1)(2)^3}{12}$$

$$e = 0.667$$

$$Ss = A\bar{y}$$

$$Ss = 2(1)(1)$$

$$Ss = 2$$

$$e = \frac{0.667}{2}$$

$$e = 0.335$$

$$y = 1 - 0.335$$

$$y = 0.665 \ \ from\ the\ hinged$$

3 Min. vol. of concrete :

$$\sum M \ \ at\ the\ hinged$$

$$P(y) = T(2.5)$$

$$T = \frac{19.62(0.665)}{2.5}$$

$$T = 5,22\,kN$$

$$T = W - BF$$

$$5.22 = V(23.6) - V(9.81)$$

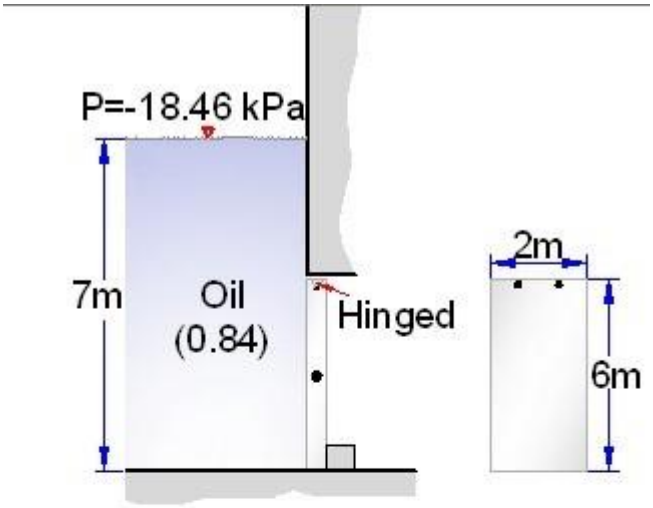
$$V = 0.379\ cu.m.$$

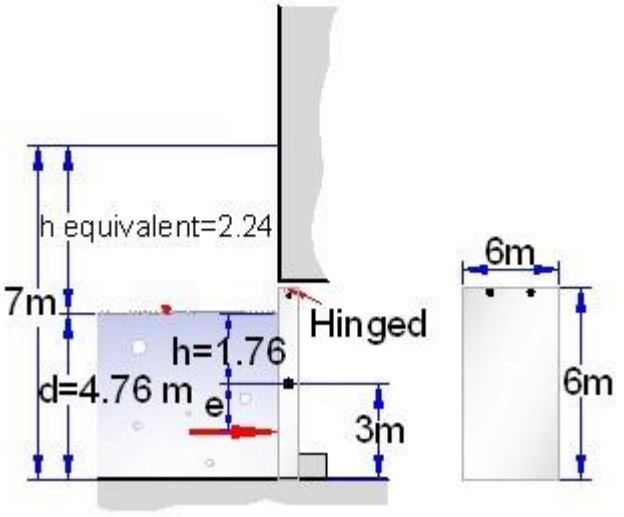
A vertical rectangular gate as shown is 2m. wide, 6m. high is hinged at the top, has oil (sp.gr. = 0.84) standing 7m. deep on one side, the liquid surface being under a pressure of 18.46 kPa.

1) **Compute the hydrostatic force acting on the gate.**

2) **How far is the force acting below the hinged.**

3) **How much horizontal force applied at the bottom is needed to open the gate.**





Solution: 7-2.24= 4.76; 4.76-(6/2) = 1.76(h)

1 Force on the liquid on the gate :

$$h\ equivalent = \frac{18.46}{9.81(0.84)}$$

$$h\ equivalent = 2.24\,m.$$

$$P = \gamma h A$$

$$P = 9.81(0.84)(1.76)(2)(6)$$

$$P = 174.04\ kN$$

2 Location of force below the hinged :

$$e = \frac{Ig}{Ah}$$

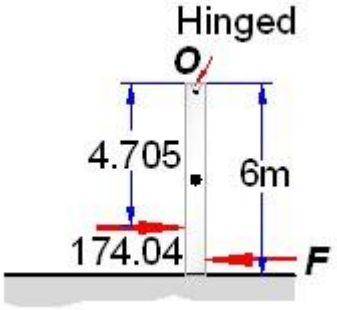
$$e = \frac{(2)(6)^3/12}{2(6)(1.76)}$$

$$e = 1.705$$

Location of force below hinged = 3 + 1.705

Location of force below hinged = 4.705 m.

3 Horizontal force needed to open the gate :



$$\sum M_O = 0$$

$$F(6) = 174.04(4.705)$$

$$F = 136.48\ kN$$

The velocity of oil flowing thru a 30mm diameter pipe is equal to 2 m/s. Oil has a kinematic viscosity of 5 x 10^{-5} m^2/s. If the pipe has a length of 120m.

1) **Compute the Reynolds Number.**

2) **Compute the friction factor.**

3) **Compute the head loss of the pipe.**

Solution:

1 Reynolds number :

$$\mathrm{Re} = \frac{DV}{\upsilon}$$

$$\mathrm{Re} = \frac{0.30(2)}{5x10^{-5}}$$

$$\mathrm{Re} = 1200 < 2000$$

2 Friction factor :

$$f = \frac{64}{\mathrm{Re}}$$

$$f = \frac{64}{1200}$$

$$f = 0.053$$

3 Head loss :

$$hf = \frac{f\,L\,V^2}{D\,2g}$$

$$hf = \frac{0.053(120)(2)^2}{0.03(2)(9.81)}$$

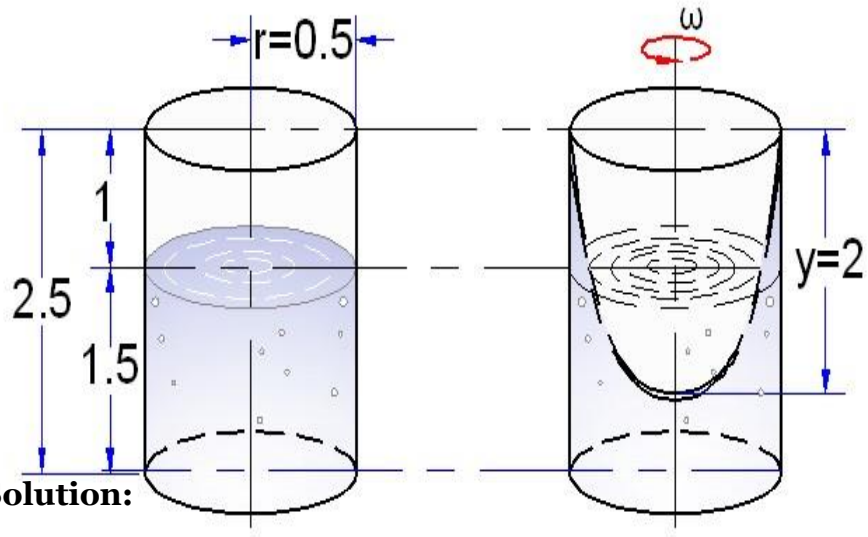
$$hf = 43.22$$

An open cylindrical tank one meter in diam. and 2.5 m. high is 3/5 full of water. If the tank is rotated about its vertical axis, what speed should it have in rpm so that:

1) **The water could just reach the rim of the tank without water being spilled out.**

2) **The depth of water at the center is zero.**

3) **There is no water at the bottom within 20 cm. from the vertical axis.**



Solution:

1 Water could just reach the rim of the tank :

$$y = \frac{\omega^2 r^2}{2g}$$

$$2 = \frac{\omega^2 (0.5)^2}{2(9.81)}$$

$$\omega = 12.53\ rad/\text{sec}.$$

$$\omega = \frac{12.53(60)}{2\pi}$$

$$\omega = 119.64\ rpm$$

2 Depth of water at the center is zero :

$$y = \frac{\omega^2 y^2}{2g}$$

$$2.5 = \frac{\omega^2 (0.5)^2}{2(9.81)}$$

$\omega = 14.01\ rad/\text{sec.}$

$$\omega = \frac{14.01(60)}{2\pi}$$

$\omega = 133.76\ rpm$

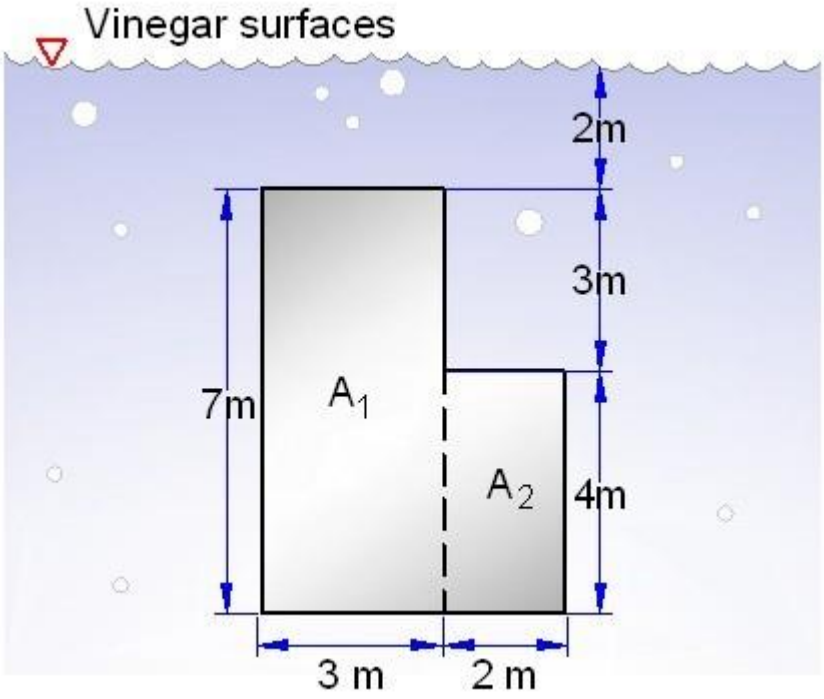
3 No water at the bottom within 20 cm. from the vertical axis :

A vertical plate shown is submerged in vinegar having a sp.gr. = 0.80. Assume unit weight of water to be 9.79 kN/m³.

1) **Find the depth of the center of pressure of section A_1 from the liquid surface.**

2) **Find the magnitude of the hydrostatic force on one side of the plate.**

3) **Find the depth of the center of pressure of the whole section from the liquid surface.**



Solution:

In A1 7/2=3.5 ; from surface to center of A1 = 2+3.5 = 5.5

1 Depth of center of pressure of section A_1 :

$$h_1 = 5.5 + e_1$$

$$e_1 = \frac{Ig}{Ss}$$

$$Ig = \frac{(3)(7)^3}{12}$$

$$Ig = 85.75$$

$$Ss = Ay$$

$$Ss = 3(7)(5.5)$$

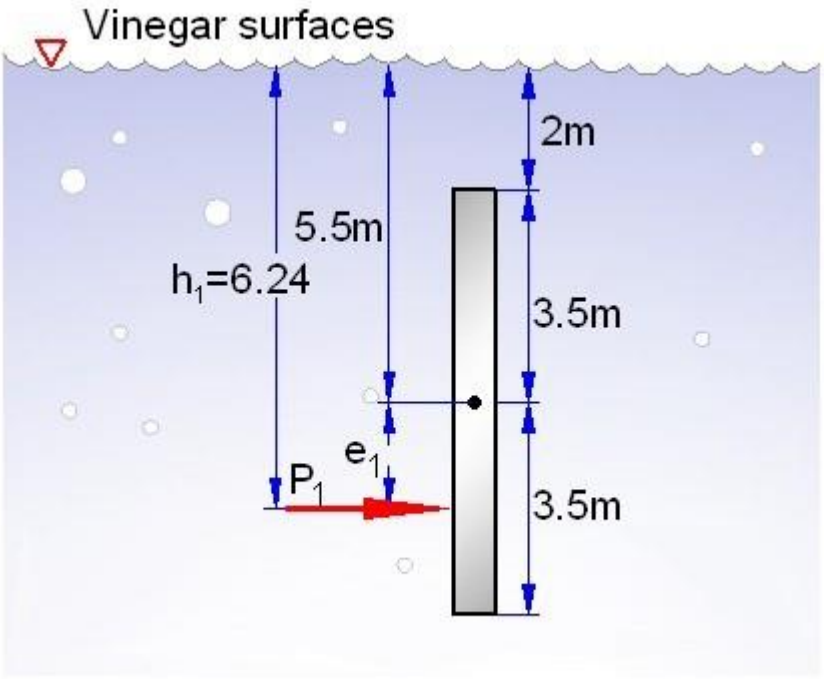
$$Ss = 115.5$$

$$e_1 = \frac{85.75}{115.5}$$

$$e_1 = 0.742$$

$$h_1 = 5.5 + 0.742$$

$$h_1 = 6.24\,m.$$



2 Magnitude of hydrostatic force :

$$P_1 = \gamma_w h A$$

$$P_1 = 9.79(5.5)(3)(7)(0.80)$$

$$P_1 = 905 kN$$

$$e_2 = \frac{Ig}{Ss}$$

$$Ig = \frac{2(4)^3}{12} = 10.67$$

$$Ss = Ay$$

$$Ss = 2(4)(7)$$

$$Ss = 56$$

$$e_2 = \frac{10.67}{56} = 0.19$$

$$h_2 = 7 + 0.19$$

$$h_2 = 7.19 m.$$

$$P_2 = \gamma_w h A$$

$$P_2 = 439 kN$$

$$P = P_1 + P_2$$

$$P = 905 + 439$$

$$P = 1344\ kN$$

3 Depth of center of pressure :

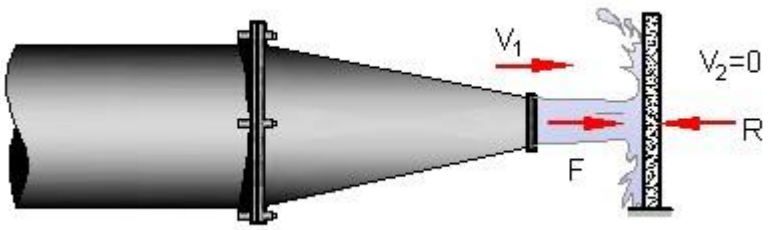
$$P h_c = P_1 h_1 + P_2 h_2$$

$$1344\ h_c = 905(6.24) + 439(7.19)$$

$$h_c = 6.55 m.$$

A jet of water 250 mm in diameter impinges normally on a flat steel plate. If the discharge is 0.491 m^3/s.

1) **Find the force exerted by the jet on the stationary plate.**
2) **If the flat plate is moving at 2 m/s in the same direction as that of the jet find the force exerted by the jet on the plate.**
3) **If the plate moving a 4 m/s in the same direction as that of the jet, find the work done on the plate per second.**



Solution:

1 Fiorce exerted by the jet on the stationary plate :

$$F = R$$

$$-R = \frac{Q\gamma_w}{g}(V_2 - V_1)$$

$$Q = AV$$

$$0.491 = \frac{\pi}{4}(0.25)^2 V_1$$

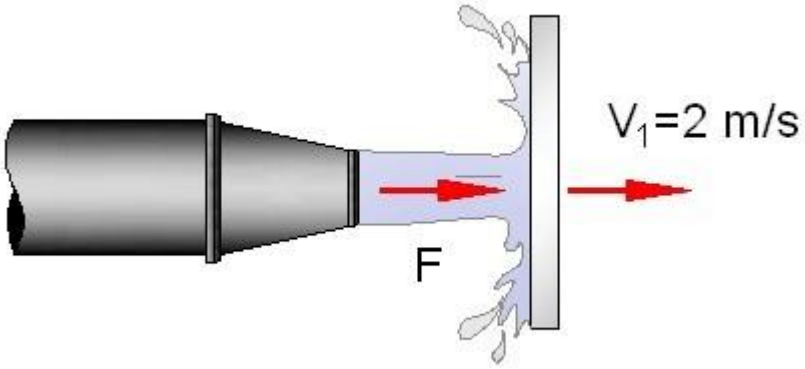
$$V_1 = 10 m/s$$

$$-R = \frac{0.491(9.81)}{9.81}(0-10)$$

$$R = 4.91 kN$$

2 Force exerted by the jet on the plate if the plate is moving at

2 m / s in the same direction at the jet :



$$F = \rho A\left(V - V_1\right)^2$$

$$F = 1000\left(\frac{\pi}{4}\right)(0.25)^2\,(10-2)^2$$

$$F = 3142\,N$$

$$F = 3.142\ kN$$

3 Work done per second if the plate is moving at 4 m / s in the same direction as the jet :

$$F = \rho A\left(V - V_1\right)^2$$

$$F = 1000\left(\frac{\pi}{4}\right)(0.25)^2\,(10-4)^2$$

$$F = 1767\,N$$

$$Work\ done = 1767\,(4)(1)$$

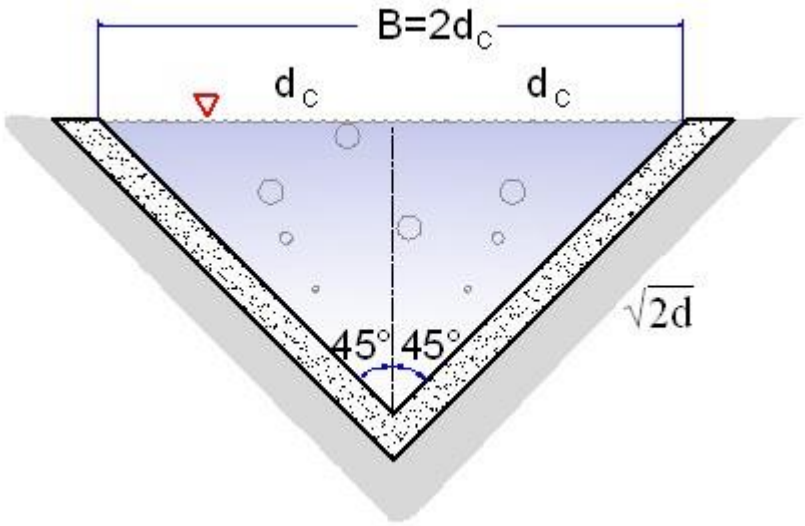
$$Work\ done = 7068\ N.m/\text{sec}.$$

The cross section of a right triangular channel is shown with a coefficient of roughness n = 0.012. If the rate of flow = 4 m^3/s.

1) **Compute the critical depth.**

2) **Compute the critical velocity.**

3) **Compute the critical slope.**



Solution:

1 Critical depth :

$$A = \frac{2d_c d_c}{2} = d_c^2$$

$$B = 2d_c$$

$$\frac{Q^2}{g} = \frac{A^3}{B}$$

$$\frac{(4)^2}{9.81} = \frac{\left(d_c^2\right)^3}{2d_c}$$

$$d_c^5 = 3.26$$

$$d_c = 1.267\,m.$$

2 Critical velocity :

$$V_c = \sqrt{g\frac{A}{B}}$$

$$A = (1.267)^2$$

$$A = 1.605\,m^2$$

$$B = 2(1.267)$$

$$B = 2.534$$

$$V_c = \sqrt{\frac{9.81(1.605)}{2.534}}$$

$$V_c = 2.49\,m/s$$

3 Critical slope :

$$V_c = \frac{1}{n}R^{2/3}S_c^{1/2}$$

$$P = 2\sqrt{2}\,d_c$$

$$P = 2\sqrt{2}(1.267)$$

$$P = 3.58$$

$$R = \frac{A}{P}$$

$$R = \frac{1.605}{3.58}$$

$$R = 0.448$$

$$2.49 = \frac{1}{0.012}(0.448)^{2/3}\,S_c^{1/2}$$

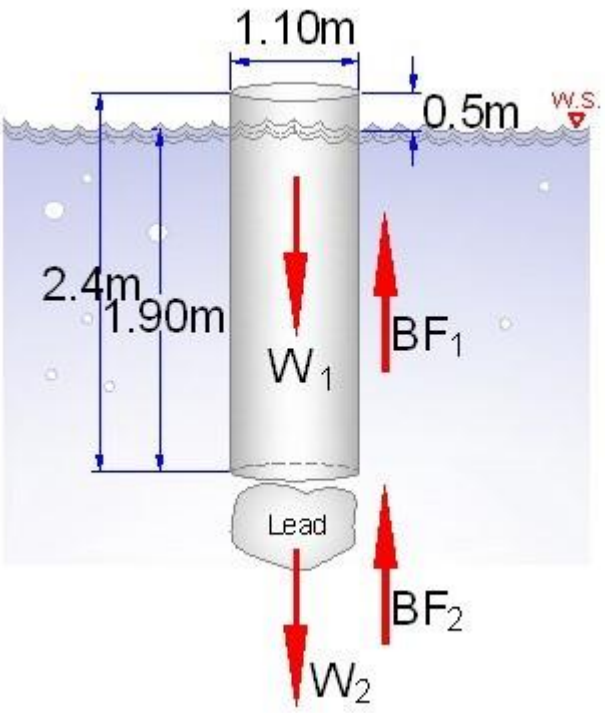
$$S_c = 0.0026$$

A hollow cylinder 1.1m. in diameter and 2.4m. long weights 3825 N.

1) **How many kN of lead weighing 110 kN/m³ must be fastened to the outside bottom to make the cylinder float vertically with 1.9m. submerged in fresh water?**

2) **How many kN of lead weighing 110 kN/m³ must be placed inside the cylinder to make the cylinder float vertically with 1.90m. submerged in fresh water?**

3) **What additional load must be placed inside the cylinder to make the top of the cylinder flush with the water surface?**



Solution:

[1] Load placed outside the bottom of cylinder :

$$W_1 + W_2 = BF_1 + BF_2$$

$$3.825 + W_2 = \frac{\pi}{4}(1.1)^2(1.9)(9.81) + V(9.81)$$

$$V = \frac{W_2}{D}$$

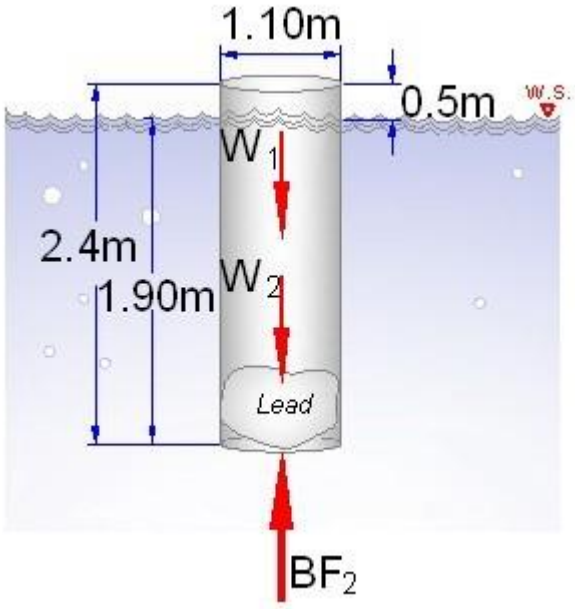
$$V = \frac{W_2}{110}$$

$$3.825 + W_2 = 17.71 + \frac{W_2(9.81)}{110}$$

$$W_2 = 15.24\,kN$$

$$W_2 = 15240\ N$$

[2] Load placed inside the cylinder :



$$W_1 + W_2 = BF$$

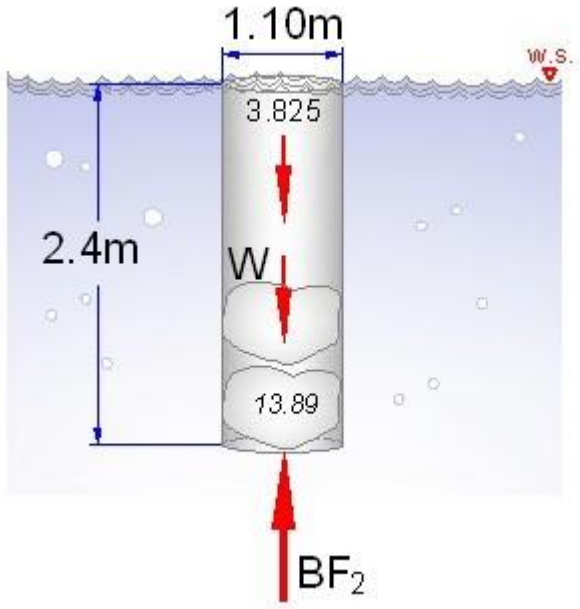
$$3.825 + W_2 = \frac{\pi}{4}(1.1)^2(1.9)(9.81)$$

$$W_2 = 13.89\,kN$$

$$W_2 = 13890\,N$$

3 Additional load to make the top flush

with the water surface :



$$3.825 + W_1 + 13.89 = BF$$

$$3.825 + W + 13.89 = \frac{\pi}{4}(1.1)^2(2.4)(9.81)$$

$$W = 4.66\,kN$$

$$W = 4660\,N$$

Check :

$$W = \frac{\pi}{4}(1.1)^2(0.50)(9.81)$$

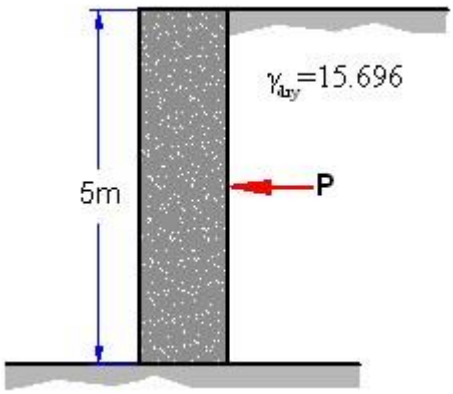
$$W = 4.66\,kN$$

A retaining wall 5m. high is supporting a horizontal back fill having a dry unit weight of 1600 kg/m³. The cohesion less soil has an angle of friction of 32°.

1) **Compute the Rankine active force on the wall.**

2) **Compute the Rankine active force on the wall if the water table is located at a depth of 2.5m. below the ground surface. The saturated unit weight is 18.7 kN/m³.**

3) **Compute the location of the resultant active force from the bottom for the second condition.**



Solution:

1 Rankine active force when the soil is dry :

$$P = \frac{1}{2}\gamma_s \, K_a \, h^2$$

$$K_a = \frac{1 - Sin\phi}{1 + Sin\phi}$$

$$K_a = \frac{1 - Sin32^\circ}{1 + Sin32^\circ}$$

$$K_a = 0.307$$

$$\gamma_s = 1600(9.81)$$

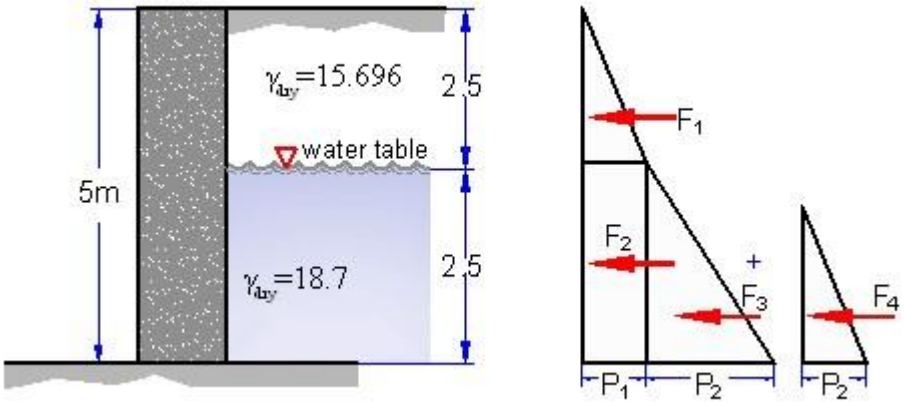
$$\gamma_s = 15696 \; N/m^3$$

$$P = \frac{1}{2}(15.696)(0.307)(5)^2$$

$$P = 60.23 kN$$

2 Rankine active force when the water table is located

2.5m. below the ground surface :



$$P_1 = 15.696(2.5)(0.307)$$

$$P_1 = 12.05\ kN/m^2$$

$$P_2 = (18.7 - 9.81)(2.5)(0.307)$$

$$P_2 = 6.82\ kN/m^2$$

$$P_3 = 9.81(2.5)$$

$$P_3 = 24.53\ kN/m^2$$

$$F_1 = \frac{12.05(2.5)}{2}$$

$$F_1 = 15.03\,kN$$

$$F_2 = 12.05(2.5)$$

$$F_2 = 30.13\,kN$$

$$F_3 = \frac{6.82(2.5)}{2}$$

$$F_3 = 8.53\,kN$$

$$F_4 = \frac{24.53(2.5)}{2}$$

$$F_4 = 30.66\,kN$$

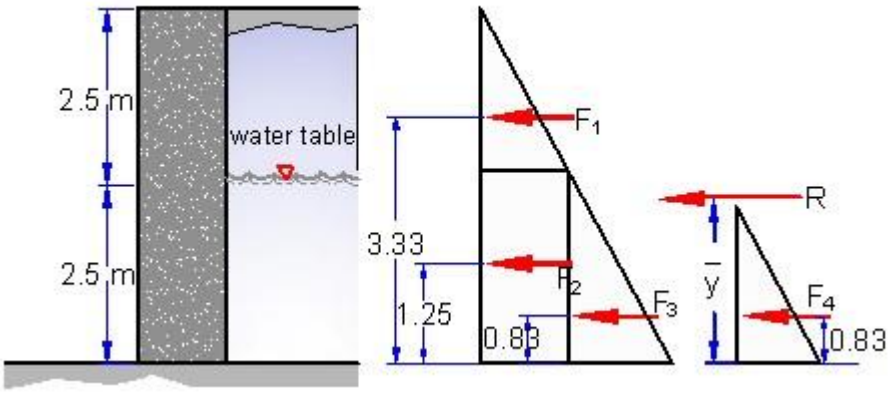
Total force R :

$$R = F_1 + F_2 + F_3 + F_3$$

$$R = 15.06 + 30.13 + 8.53 + 30.66$$

$$R = 84.38\ kN$$

3 Location of the resultant active force :



$$R\bar{y} = F_1(3.33) + F_2(1.25) + F_3(0.83) + F_4(0.83)$$

$$84.38\bar{y} = 15.06(3.33) + 30.13(1.25) + 8.53(0.83) + 30.66(0.83)$$

$$\bar{y} = 1.43m.$$

The field unit weight of the soil sample is 1960 kg/m^3 and the unit weight of the soil particle is 2700 kg/m^3. If the e_{max} = 0.69 and e_{min} =
0.44.

1) **Compute the dry unit weight in kN/m^3 if the water content is 11%.**

2) **Compute the void ratio of the soil sample.**

3) **Compute the relative density of the soil sample.**

Solution:

1 Dry unit weight of soil :

$$G_s = \frac{\gamma_s}{1000}$$

$$G_s = \frac{2700}{1000}$$

$$G_s = 2.70$$

$$\gamma_{dry} = \frac{\gamma_{moist}}{1+\omega}$$

$$\gamma_{dry} = \frac{1960}{1+0.11}$$

$$\gamma_{dry} = 1765.8\ kg/m^3$$

$$\gamma_{dry} = \frac{1765.8(9.81)}{1000}$$

$$\gamma_{dry} = 17.32\ kN/m^3$$

2 Void ratio :

$$\gamma_{dry} = \frac{(G_s + e)\gamma_w}{1+e}$$

$$17.32 = \frac{2.70(9.81)}{1+e}$$

$$e = 0.53$$

3 Relative density of soil :

$$D_r = \frac{e_{max} - e}{e_{max} - e_{min}}$$

$$D_r = \frac{0.69 - 0.53}{0.69 - 0.44}$$

$$D_r = 0.64$$

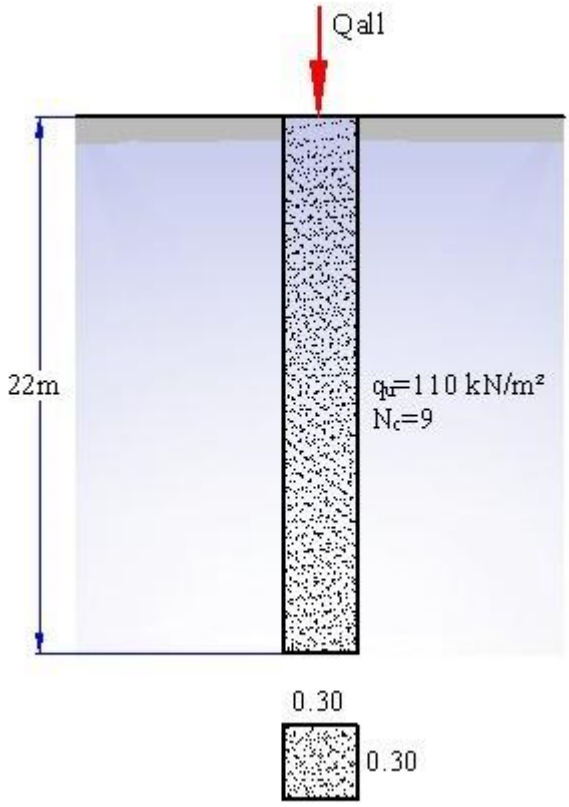
$$D_r = 64\%$$

A 0.30m. x 0.30m concrete pile 22m. long is driven in a clayey soil having an unconfined compressive strength of 110 kN/m². The unit weight of clayey soil is 18 kN/m³. Frictional constant is 0.76 due to skin friction. Assume a factor of safety equal to 2.0 and a bearing capacity factor $N_c = 9$.

1) **Compute the capacity of pile due to skin friction only.**

2) **Compute the end bearing capacity of pile.**

3) **Compute the design capacity of the concrete pile.**



Solution:

1 Capacity of pile due to friction only :

$$Q_1 = \alpha P C L$$

$$C = \frac{1}{2} q_u$$

$$C = \frac{1}{2}(110)$$

$$C = 55 kPa$$

$$Q_1 = 0.76(4)(0.30)(55)(22)$$

$$Q_1 = 1103.52\ kN$$

2 End bearing capacity of piles ::

$$Q_b = c\, N_c\, A_{tip}$$

$$Q_b = 55(9)(0.3)(0.3)$$

$$Q_b = 44.55\ kN$$

3 Design Capacity :

$$Q_{all} = \frac{Q_f + Q_b}{F.S.}$$

$$Q_{all} = \frac{(1103.52 + 44.55)}{2}$$

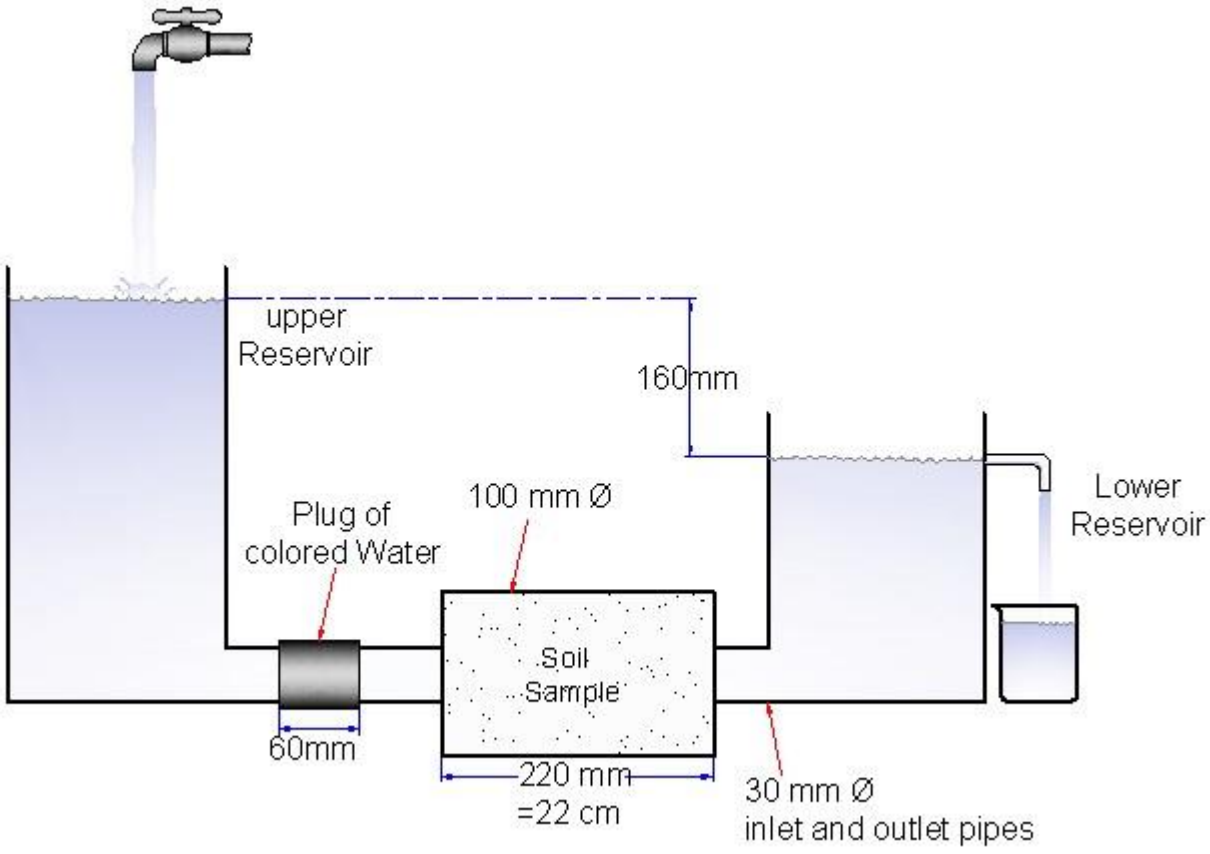
$$Q_{all} = 574.04\ kN$$

The laboratory apparatus shown in the figure maintains a constant head in both the upper and lower reservoirs. The soil sample is a silty sand with a hydraulic conductivity K = 5 x 10^{-3} cm/sec. and a moisture content of 18.5%. Specific gravity of soil sample is 2.70.(2005)

1) **Compute the seepage velocity in cm/sec.**

2) **Determine the time required for the plug of colored water to pass through the soil. Assume also that the colored water has the same unit weight and viscosity as plain water.**

3) **Compute the discharge of water.**



Solution:

[1] Seepage velocity :

$$S = \frac{\omega G_s}{e}$$

$$100 = \frac{18.5(2.7)}{e}$$

$$e = 0.50$$

$$i = \frac{h}{L}$$

$$i = \frac{160}{220}$$

$$i = 0.73$$

$$V = Ki$$

$$V = 5x10^{-3}(0.73)$$

$$V = 3.65x10^{-3}\, cm/\text{sec.}$$

$$n = \frac{e}{1+e}$$

$$n = \frac{0.50}{1+0.50}$$

$$n = 0.33$$

$$V_s = \frac{V}{n}$$

$$V_s = \frac{3.65x10^{-3}}{0.33}$$

$$V_s = 0.011 cm/\text{sec.}(\textit{seepage velocity})$$

[2] Time the colored water pass through the soil :

$$T = \frac{D}{V_s} = \frac{22}{0.011}$$

$$T = 2000\,\text{sec.}$$

$$T = 33.33\,\text{min.}$$

[3] Discharge :

$$Q = KiA$$

$$Q = 5x10^{-3}(0.73)\frac{\pi(10)^2}{4}$$

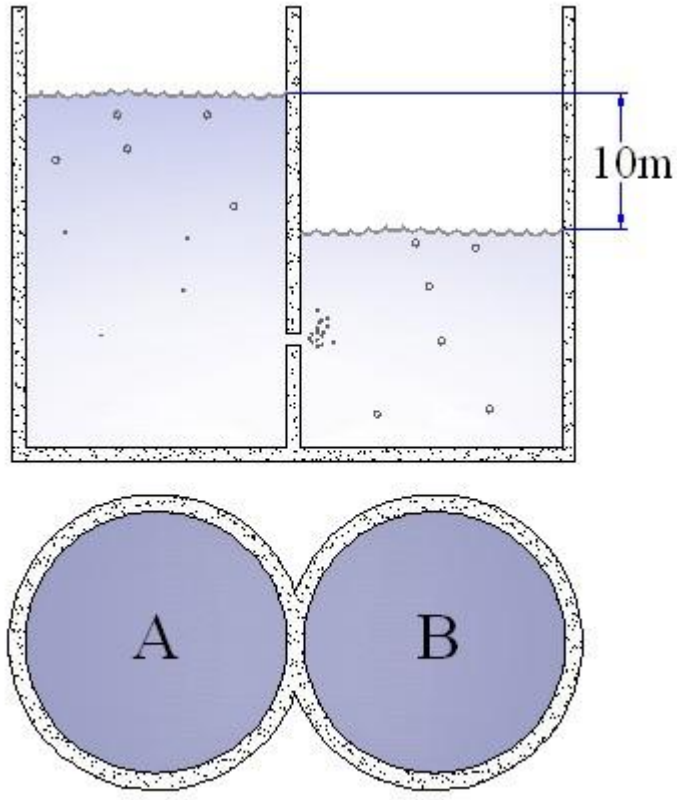
$$Q = 0.287\, m^3/s$$

Two open cylindrical tanks are connected by an orifice having a cross sectional area of 0.004 m². Tank A is 8m. in diam. and its water level is 10m. above that of B whose diameter is 5m. If the coeff. Of discharge is
0.60.

1) **Find the discharge flowing in the orifice.**

2) **How long will it be before the water surfaces are at the same level?**

3) **How soon after will the water surfaces be 4m. apart?**



Solution:

1 Discharge flowing in the orifice :

$$Q = CA\sqrt{2gh}$$

$$Q = 0.60(0.004)\sqrt{2(9.81)(10)}$$

$$Q = 0.034\ m^3/s$$

2 Time for the water surface to be at the same level :

$$t = \frac{2AB\sqrt{h}}{(A+B)C\,A_s\sqrt{2g}}$$

$$A = \frac{\pi(8)^2}{4} = 50.27\,m^2$$

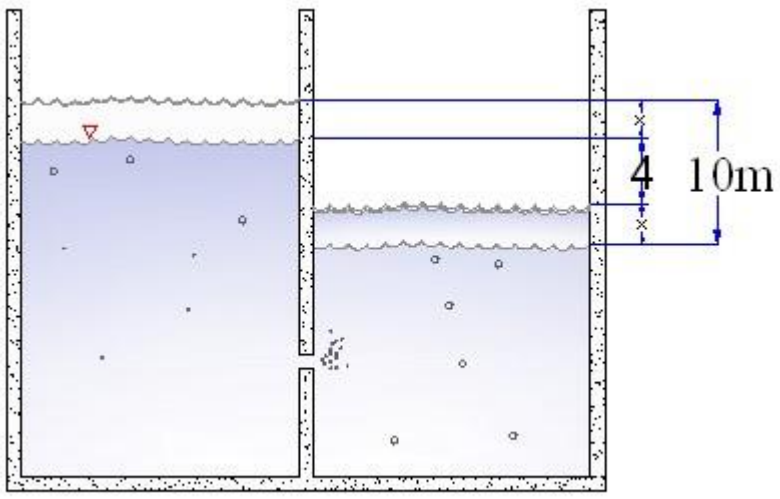
$$B = \frac{\pi(5)^2}{4} = 19.63\,m^2$$

$$t = \frac{2(50.27)(19.63)\sqrt{10}}{(50.27+19.63)(0.60)(0.004)\sqrt{2(9.81)}}$$

$$t = 8399\,\text{sec.}$$

$$t = 2.33\,hours$$

3 Time the water surface be 4m. apart :



$$x + 4 + y = 10$$

$$x + y = 6$$

$$Ax = By$$

$$50.27x = 19.63y$$

$$y = 2.56x$$

$$x = 1.69$$

Vol. of H_2O flowing out of A

$$\text{Vol.} = 50.27(1.69)$$

$$\text{Vol.} = 84.96\,m^3$$

$$Q_{ave} = \frac{CA\sqrt{2g}\left(\sqrt{h_1} + \sqrt{h_2}\right)}{2}$$

$$Q_{ave} = \frac{0.60(0.004)\sqrt{2(9.81)}\left(\sqrt{10} + \sqrt{4}\right)}{2}$$

$$Q_{ave} = 0.027\,m^3$$

$$t = \frac{Vol.}{Q_{ave}}$$

$$t = \frac{84.96}{0.027}$$

$$t = 3147 \text{ sec.}$$

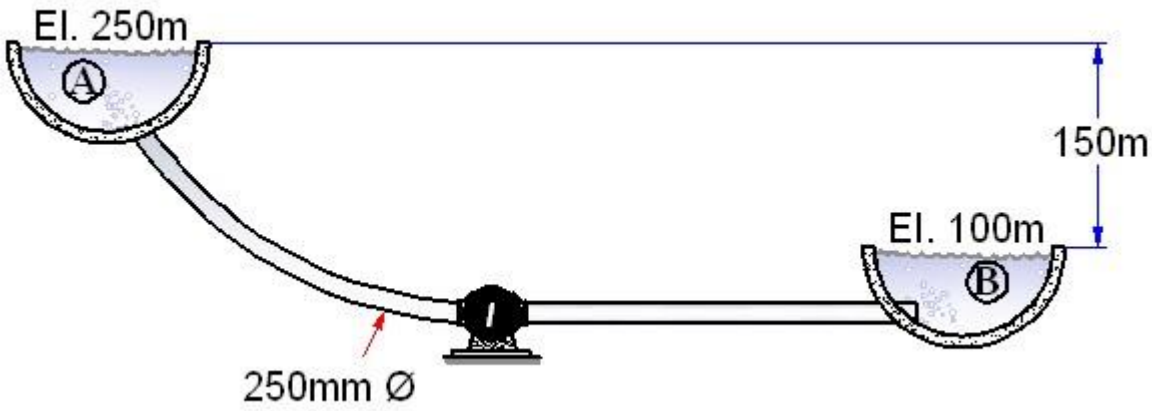
$$t = 52.45 \text{ min}$$

Two reservoirs A and B have elevations of 250 m and 100m respectively. It is connected by a pipe having a diameter of 25 mm Ø and a length of
100m. A turbine is installed at point in between reservoirs A and B. If C = 120, compute the following if the discharge flowing in the pipe is 150 liters/sec.(2005)

1) **Head loss of pipe due to friction.**

2) **The head extracted by the turbine.**

3) **The power generated by the turbine.**



Solution:

1 Head extracted by the turbine :

$$hf = \frac{10.64\, L Q^{1.85}}{C^{1.85} D^{4.87}}$$

$$Q = 0.14\ m^3/s$$

$$hf = \frac{10.64(100)(0.15)^{1.85}}{(120)^{1.85}(0.25)^{4.87}}$$

$$hf = 3.87\, m.$$

2 Head extracted by the turbine :

$$\frac{V_A^2}{2g} + \frac{P_A}{\gamma_w} + Z_A = \frac{V_B^2}{2g} + \frac{P_B}{\gamma_w} + Z_B + HE + HL$$

$$0 + 0 + 250 = 0 + 0 + 100 + HE + 3.87$$

$$HE = 250 - 103.87$$

$$HE = 146.13\, m.$$

3 Power generated by the turbine :

$$Power = QWE$$

$$Power = 0.15(9810)(146.13)$$

$$Power = 215030\, watts$$

$$Power = 215.03\, kW$$

discharge of 750 liters/sec. flows through a pipe having a diameter of 400 mm Ø. Length of 65m. long, compute the head loss of the pipeline using(2005)

1) Mannings Equation with n=0.013 2)

Darcy Weishback formula with f =

0.012.

3) Hazen Williams Formula with C = 100.

Solution:

1 Mannings Formula :

$$V = \frac{1}{n} R^{2/3} S^{1/2}$$

$$V = \frac{0.75}{\frac{\pi}{4}(0.4)^2}$$

$$V = 5.97\, m/s$$

$$R = \frac{D}{4}$$

$$R = \frac{0.4}{4} = 0.1$$

$$5.97 = \frac{(0.1)^{2/3} S^{1/2}}{0.013}$$

$$S = \frac{hf}{L}$$

$$hf = 0.130(65)$$

$$hf = 8.45 m.$$

2 Darcy Weishback :

$$hf = \frac{0.0826 f L Q^2}{D^5}$$

$$hf = \frac{0.0826(0.012)(65)(0.75)^2}{(0.4)^5}$$

$$hf = 1.96 m.$$

3 Hazen Williams :

$$V = 0.8492 C R^{0.63} S^{0.54}$$

$$5.97 = 0.8492(100)(0.1)^{0.63} S^{0.54}$$

$$S^{0.54} = 0.2999$$

$$S = 0.1075$$

$$hf = 0.1075(65)$$

$$hf = 6.99\ m.$$

A vertical tank having a horizontal cross-sectional area of 0.4 square meter has 0.0003m² orifice at its bottom. The initial head on the orifice is h_1 = 1.2m. It takes 312 second for the water level to drop from 1.2m to
0.6m.

1. What is the coefficient of discharge?
2. If C = 0.6, how long will it take for the water level to drop from 1.2m to 0.8m?
3. If C = 0.6, what is the head on the orifice after 240?

Solution:

Since the cross - sectional area of the tank is constant, the time for the head to change from H_1 *to* H_2 *is* :

$$t = \frac{2A_s}{CA_0\sqrt{2g}}\left(\sqrt{H_1} - \sqrt{H_2}\right)$$

$$t = \frac{2(0.4)}{C(0.0003)\sqrt{2(9.81)}}\left(\sqrt{H_1} - \sqrt{H_2}\right) = \frac{602.03}{C}\left(\sqrt{H_1} - \sqrt{H_2}\right)$$

$$t = \frac{60.203}{C}\left(\sqrt{H_1} - \sqrt{H_2}\right)$$

1

$$t = 312s,\ H_1 = 1.2m,\ H_2 = 0.6m$$

$$312 = \frac{602.03}{C}\left(\sqrt{1.2} - \sqrt{0.6}\right)$$

$$C = 0.062$$

2

$$C = 0.6,\ H_1 = 1.2m,\ H_2 = 0.8m$$

$$t = \frac{60.203}{C}\left(\sqrt{H_1} - \sqrt{H_2}\right) = \frac{602.03}{0.6}\left(\sqrt{1.2} - \sqrt{0.8}\right)$$

$$t = 201.7\ seconds$$

3

$$C = 0.60,\ H_1 = 1.2m,\ t = 240\text{sec}$$

$$t = \frac{60.203}{C}\left(\sqrt{H_1} - \sqrt{H_2}\right)$$

$$240 = \frac{602.03}{0.6}\left(\sqrt{1.2} - \sqrt{H_2}\right);\ H_2 = 0.733m$$

Water flow at the rate of 1.2 m^3/s at a depth of 1.5m in a 10-m wide irrigation canal. Assume uniform flow and use n = 0.035.

1. Calculate the nearest value to the specific energy in Joule/Newton.

2. Determine the slope of the channel bed in meter per kilometer.

3. Determine the boundary shearing stress at the walls in Pa.

Solution:

1

Width, $b = 10m$ $\qquad$ $Depth, d = 1.5m$

Area, $A = bd = 10(1.5) = 15m^2$

Wetted perimeter, $P = b + 2d = 10 + 2(1.5) = 13m$

Hydraulic radius, $R = A/P = 15/13 = 1.1538m$

Mean velocity, $v = \frac{Q}{A} = \frac{1.2}{15} = 0.08m/s$

Specific energy, $H = \frac{v^2}{2g} + d = \frac{0.08^2}{2(9.81)} + 1.5 = 1.5003m$

Specific energy, $H = 1.5003$ *Joule/Newton*

2

$\left(v = \frac{1}{n} R^{2/3} S^{1/2}\right)$ $\quad 0.08 = \frac{1}{0.035}(1.1538)^{2/3} S^{1/2}$

$$S = 0.0000064785$$

Slope of channel bed, $S_0 = S = 0.0000064785 = 0.0064785 m/km$

3

Boundary shear stress :

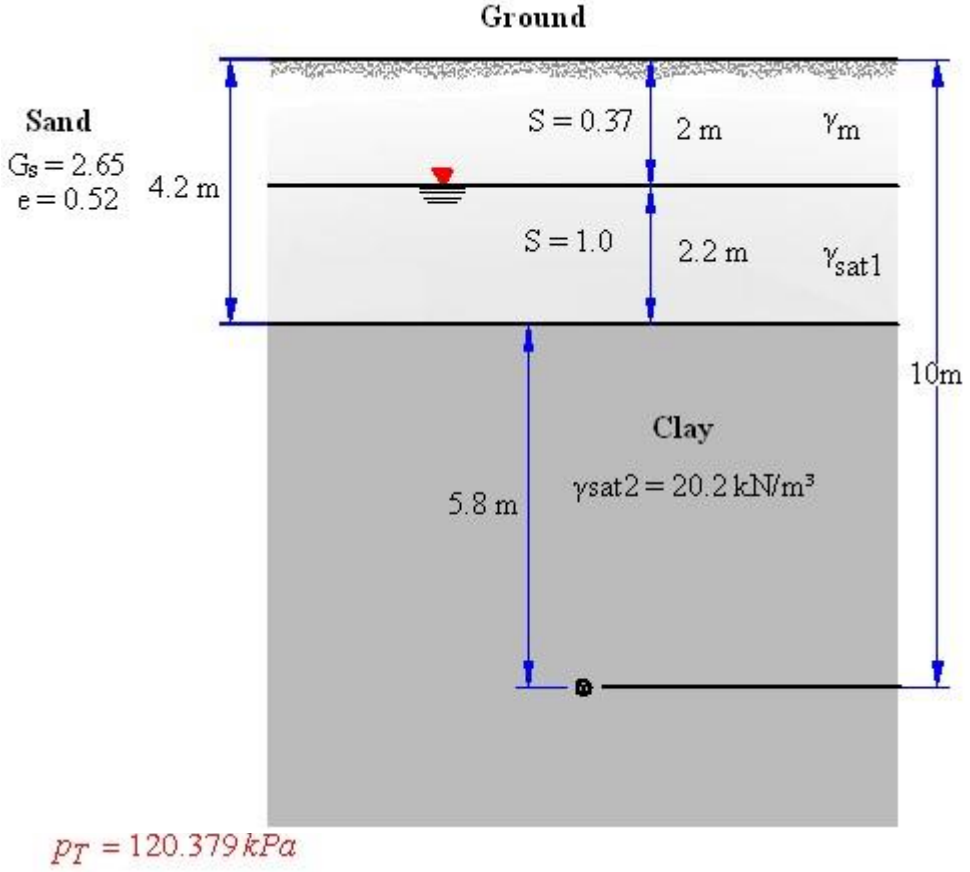
$[\tau_s = \gamma RS]$ $\quad \tau_s = 9810(1.1538)(0.0000064785)$

$$\tau_s = 0.0733 Pa$$

A 4.2m thick layer of sand is underlain by a layer of clay. The water table is 2m below the ground (sand) surface. For sand, G_s = 2.65 and the average void ratio is 0.52. The sand above water table has a degree of saturation of 0.37. The saturated nit weight of the clay layer is 20.2 kN/m3.

$$\gamma_m = \left[\frac{G + Se}{1+e}\gamma_w\right] \qquad \gamma_m = \frac{2.65 + 0.37(0.52)}{1+0.52}(9.81)$$

$\gamma_m = 18.345\ kN/m^3$



$p_T = 120.379\ kPa$

1. Determine the unit weight of sand above water table in kN/m3

2. Determine the total stress at a point 10m below the ground.

3. Determine the effective stress at a point 10m below the ground.

Solution:

A soil sample taken from subgrade have a density of 1900 kg/m3 with moisture content of 11%. Laboratory tests reveals that the soil solids have density of 2660 kg/m3 and the maximum and minimum void ratios of the soil mass are 0.63 and 0.44, respectively.

1. Determine the nearest value to the dry unit weight of the soil in kN/m3.

2. Determine the relative density of the sample.

3. Determine the relative density of the sample.

Solution:

$\rho_m = 1900\,kg/m^3$ $\quad MC = 0.11$

$G = \dfrac{2660}{1000} = 2.66$ $\quad e_{max} = 0.63$ $\quad e_{min} = 0.44$

$\left[\rho_m = \dfrac{G + GMC}{1+e}\rho_w\right]$ $\quad 1900 = \dfrac{2.66 + 2.66(0.11)}{1+e}(1000)$

$e = 0.554$

$\left[\gamma_d = \dfrac{G}{1+e}\gamma_w\right]$ $\quad \gamma_d = 16.79\,kN/m^3$

$\left[D_r = \dfrac{e_{max} - e}{e_{max} - e_{min}}\right]$ $\quad D_r = 0.4$

A calibration test of a 0.00785-m² circular sharp-edged orifice in a vertical side of a large tank showed a discharge of 22,300 N of water in 1minute & 40 seconds at a constant head of 1.20m. Measurement of the jet showed that it traveled 1.92m horizontally while dropping 0.8m.

1. Determine the coefficient of discharge.
2. Determine the coefficient of velocity.
3. Determine the coefficient of contraction.

Solution:

$Head,\ H = 1.2m$

$A_0 = 0.00785\,m^2$

$Theoretical\ velocity,\ v_t = \sqrt{2gH} = 4.8522\ m/s$

$Theoretical\ discharge,\ Q = A_0 v_t = 0.03809\ m/s$

Actual Discharge :

$$Q = W/t = 22300/\left[(60+40)\right] = 223\,N/s = 0.02273\,m^3/s$$

Actual velocity :

$$y = x\tan\theta - \frac{gx^2}{2v_o^2\cos^2\theta};\ \theta = 0°;\ x = 1.92m;\ y = 0.8m$$

$$v = v_o\ 4.75418\,m/s$$

$Coefficient\ of\ discharge,\ C = Q/Q_t = 0.5968$

$Coefficient\ of\ velocity,\ C_v = v/v_t = 0.9798$

$Coefficient\ of\ contraction,\ C_c = C/C_t = 0.6091$

Water is flowing in a 200-mm diameter rigid pipe that is 650m long. The increase in pressure caused by instantaneous closure of the valve near the exit is 700kPa. Bulk modulus of elasticity of water is 2.07 x 10^9 Pa.

1. What is the celerity of pressure wave in m/s?

2. What is the maximum discharge in m^3/s?

3. What water hammer pressure is expected if the valve is closed in 3 seconds?

Solution:

$$Celerity, c = \sqrt{\frac{E_\beta}{\rho}} \qquad c = \sqrt{\frac{2.07\times10^9}{1000}} = 1438.75 m/s$$

$$\left[p_h = \rho c v\right] \qquad v = \frac{p_h}{\rho c} = \frac{700000}{1000(1438.75)}$$

$$v = 0.4865 m/s$$

$$\left[Q = Av\right] \qquad Q = \frac{\pi}{4}(0.2)^2(0.4865) = 0.015285 m^3/s$$

$$t_c = 3s$$

Time for the pressure wave to travel round trip

$$t_r = \frac{2L}{c} = \frac{2(650)}{1438.75} = 0.903$$

$$Since\ t_c > t_r, slow\ closure$$

$$p_h = \frac{2Lv\rho}{t_c} = \frac{2(650)(0.4865)(1000)}{3} = 210,831 Pa$$

$$p_h = 210.8 kPa$$

Given the following laboratory result of a sub grade material:

γ_d max = 1.735 g/cc **Wet weight = 2200 g**

MC $_{max}$ = 15.75% **Dry weight = 1879 g**

Volume of soil = 1130 cc

1. Determine the dry unit weight of the soil in grams/cc.

2. Determine the moisture content in percent.

3. Determine the percent compaction and indicate whether it is adequate as subgrade material.

$$\text{Moist unit weight, } \gamma_m = \frac{Wet\ weight}{Volume}$$

$$\text{Moist unit weight, } \gamma_m = \frac{2200}{1130} = 1.947\ grm/cc$$

$$\text{Dry unit weight, } \gamma_d = \frac{Dry\ weight}{Volume}$$

$$\text{Dry unit weight, } \gamma_d = \frac{1879}{1130} = 1.663\ grm/cc$$

$$\left[\gamma_d = \frac{\gamma_m}{1+MC}\right] \qquad 1.663 = \frac{1.947}{1+MC}$$

$$MC = 0.171 = 17.1\%$$

$$\text{Percent compaction} = \frac{\gamma_d}{\gamma_{d\,\max}} \times 100\% = \frac{1.663}{1.735} \times 100\%$$

$$\text{Percent compaction} = 95.84\%$$

Note: Compaction to 95 percent of maximum density is required for all cohesive material that lies within 12 inches of the pavement surface.

Therefore, this soil compaction is adequate.
A cylindrical mold 5" in diameter is filled with silt to height H_1 = 0.2 ft, whose coefficient of permeability $k_1 = 3.6 \times 10^{-4}$ ft/min.

A second coaxial mold is placed on top of the first mold whose inside diameter is d = 1.5" and whose height is H_2 = 0.40 ft. Its thickness is negligible. The inside of this second mold is filled with the same silt, but the annular ring outside the small tube and outer tube is filled with sand whose coefficient of permeability is $k_2 = 2.7 \times 10^{-3}$ ft/min.

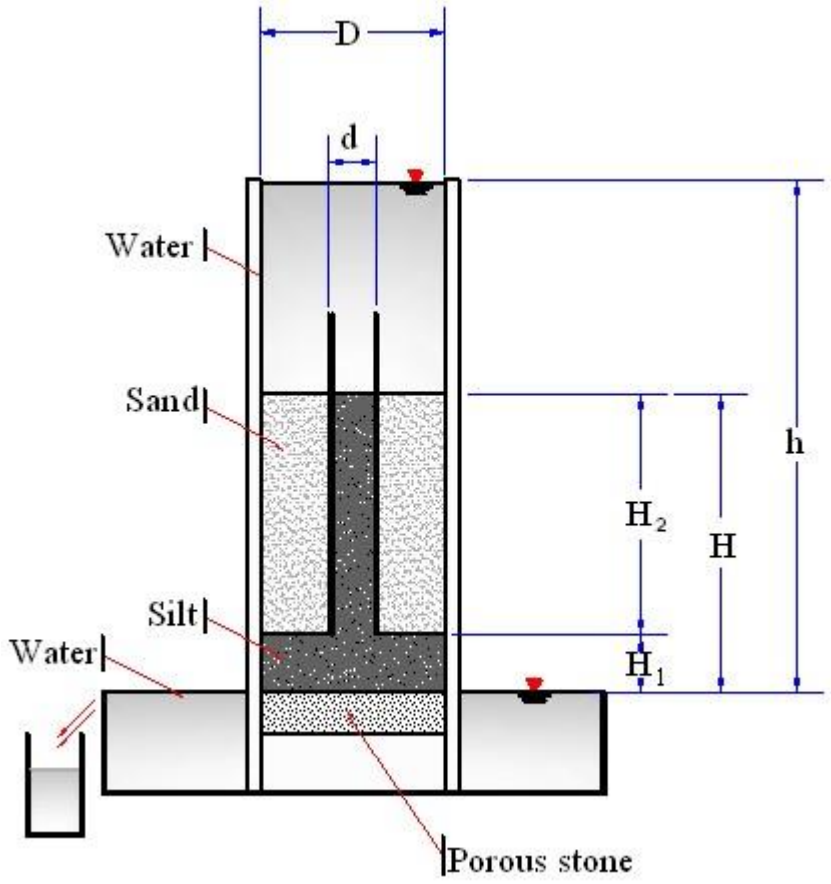
The test set-up is permeameter of constant head. Water is placed in the mold and maintained at a level h=1.6 ft. above the level of the outlet. It may be considered that the system consists of a fictitious soil of thickness $H = H_1 + H_2$ and coefficient of permeability k_f.

The following general equations may be useful:

1. What is the total flow of water in ft^3/min?

2. What is the equivalent coefficient of permeability, k_f, in ft/min?

3. What is the total amount of water that percolated after 45 minutes?



Solution:

1

Path a :

$$Q_a = k\,i\,A$$

$$k = 3.6\times10^{-4}\ ft/\min$$

$$i = h/L = 1.6/0.6 = 2.667$$

$$A = \frac{\pi}{4}d^2 = \frac{\pi}{4}(1.5/12)^2 = 0.01227\ ft^2$$

$$Q_a = 3.6\times10^{-4}\,(2.667)(0.01227) = 1.1781\times10^{-5}\ ft^3/\min$$

Path b :

$$Q_b = k_{eq}\,i\,A$$

$$k_{eq} = \frac{0.6}{\frac{0.4}{2.7\times10^{-3}} + \frac{0.2}{3.6\times10^{-4}}} = 8.526\times10^{-4}\ ft/\min$$

$$i = h/L = 1.6/0.6 = 2.667$$

$$A = \frac{\pi}{4}\left(D^2 - d^2\right) = \frac{\pi}{4}\left[\left(\frac{5}{12}\right)^2 - \left(\frac{5}{12}\right)^2\right] = 0.1241\,ft^2$$

$$Q_b = \left(8.526\times10^{-4}\right)(2.667)(0.1241) = 2.8212\times10^{-4}\ ft^3/\min$$

$$Q = Q_a + Q_b = 1.1781\times10^{-5} + 2.8212\times10^{-4}$$

$$Q = 2.939\times10^{-4}\ fth3/\min$$

2

$$Q_a = k_f\,i\,A$$

$$i = h/L = 1.6/0.6 = 2.667$$

$$A = \frac{\pi}{4}D^2\,\frac{\pi}{4}\left(\frac{5}{12}\right)^2 = 0.13635\,ft^2$$

$$Q = 2.939\times10^{-4}\ ft^3/\min$$

$$2.939\times10^{-4} = k_f\,(2.667)(0.13635)$$

$$k_f = 8.083\times10^{-4}\ ft/\min$$

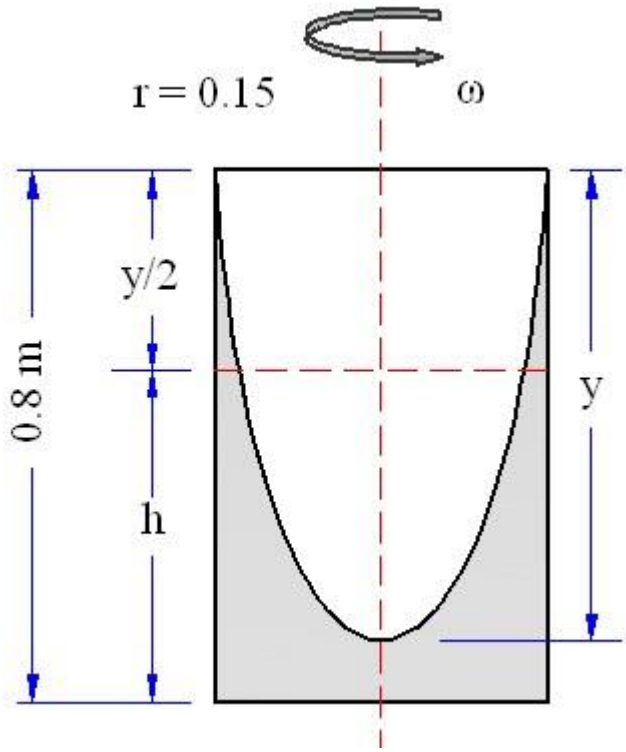
3

$$V = Q\times t = 2.939\times10^{-4}\ ft^3/\min\times45\min$$

$$V = 0.013226\,ft^3\times(100cm/3.28\,ft)^3$$

$$V = 374.8cm^3$$

An open cylindrical tank 30 cm in diameter and 80cm tall is filled with water and revolved about its own vertical axis at constant angular speed.



1. What angular speed will cause 1.4 liters of water to spill?

2. What will be the depth of water in the tank when it is brought to rest from an angular speed of 240 rpm?

3. What angular speed will just zero the pressure at the bottom?

Solution:

$$y = \frac{\omega^2 x^2}{2g}$$

1

Volume spilled = volume of paraboloid

$$0.0014 = 1/2\,\pi(0.15)^2\, y$$

$$y = 0.0396 m$$

$$\left[y = \frac{\omega^2 x^2}{2g} \right]$$

$$0.0396 = \frac{\omega^2 (0.15)^2}{2(9.81)}$$

$$\omega = 5.876\ rad/\text{sec}$$

$$\omega = 56.11\ rpm$$

2

$$x = 0.15 m$$

$$\omega = 240\ rpm = 8\pi\ rad/\text{sec};$$

$$y = \frac{(8\pi)^2 (0.15)^2}{2(9.81)} = 0.724 m$$

Depth, $h = 0.8 - y/2 = 0.438\ m$

3

$y = 0.8$ to cause zero pressure at the center

$$\left[y = \frac{\omega^2 x^2}{2g} \right] \quad 0.8 = \frac{\omega^2 (0.15)^2}{2(9.81)}$$

$$\omega = 26.412\ rad/\text{sec} = 252.22\ rpm$$

A 600-mm non-rigid pipe takes water from a large reservoir. The velocity of flow in the pipe is 2.5 m/s. The flow is suddenly stopped by a quickclosing valve situated 400 m from the reservoir. The pipe is 20mm thick and modulus of elasticity of pipe material is 1.4 x 10^{11}Pa. Bulk modulus of elasticity of water is 2.2 x 10^{9}Pa.

1. Compute for the value of the celerity of pressure wave in m/s.
2. Compute for the time for the pressure wave to travel round trip along the pipe.
3. What is the maximum water hammer pressure developed on the pipe due to instantaneous closure of the valve?

Solution: 1

$$Celerity,\ c = \sqrt{\frac{E_B}{\rho\left(1+\frac{E_B D}{E_p t}\right)}} = \sqrt{\frac{2.2\times10^9}{1000\left(1+\frac{2.2\times10^9\,(600)}{1.4\times10^{11}\,(20)}\right)}}$$

$$Celerity, c = 1{,}222.76\,m/s$$

2

$$Time,\ t_r = \frac{2L}{c} = \frac{2(400)}{1222.76}$$

$$Time, t_r = 0.654\,second$$

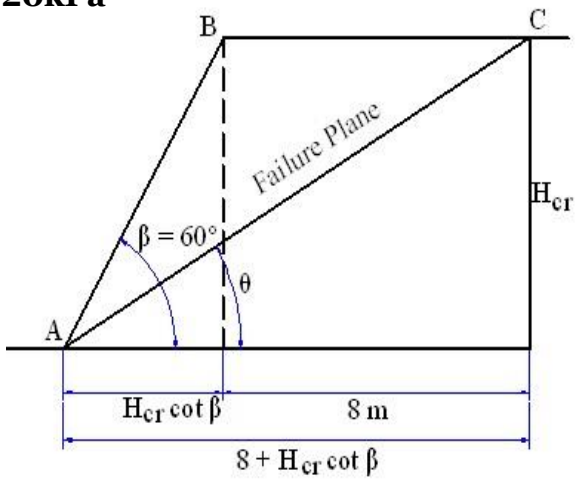
3

Water hammer pressure, $p_h = \rho c v$

Water hammer pressure, $p_h = 1000(1{,}222.76)(2.5) = 3{,}056{,}903.7\,Pa$

Water hammer pressure, $p_h = 3{,}057\,kPa$

A cut slope was excavated in a saturated clay. The slope made an angle of 60° with the horizontal. When slope failure occurs, distance BC is 8m. Given: Stability number, m=0.185: γ=17 kN/m³; c_u = 20kPa



1. What is the stability factor?

2. Determine the critical depth of cut in meters.

3. What is the angle of failure plane in degrees?

Solution:

Given : Stability number, $m = 0.185$

$\gamma = 17\,kN/m^3$

$c_u = 20kPa$

1 Stability Factor

Stability Factor = $1/m = 5.405$

2 Critical depth of excavation :

$$H_{cr} = \frac{c_u}{\gamma m} = \frac{20}{17(0.185)} = 6.359\,m$$

3 Angle of failure plane :

$$\left[\tan\theta = \frac{H_{cr}}{8 + 6.359 \times \cot 60^\circ}\right]$$

$\theta = 28.58^\circ$

Water is flowing in a 200-mm diameter rigid pipe that is 650m long. The increase in pressure caused by instantaneous closure of the valve near the exit is 700kPa. Bulk modulus of elasticity of water is 2.07 x 10^9 Pa.

1. What is the celerity of pressure wave in m/s?

2. What is the maximum discharge in m^3/s?

3. What water hammer pressure is expected if the valve is closed in 3 seconds? A. 289kPa

Solution:

$$Celerity, c = \sqrt{\frac{E_\beta}{\rho}} \qquad c = \sqrt{\frac{2.07\times10^9}{1000}} = 1438.75 m/s$$

$$[p_h = \rho c v] \qquad v = \frac{p_h}{\rho c} = \frac{700000}{1000(1438.75)}$$

$$v = 0.4865 m/s$$

$$[Q = Av] \qquad Q = \frac{\pi}{4}(0.2)^2(0.4865) = 0.015285 m^3/s$$

$$t_c = 3s$$

Time for the pressure wave to travel round trip

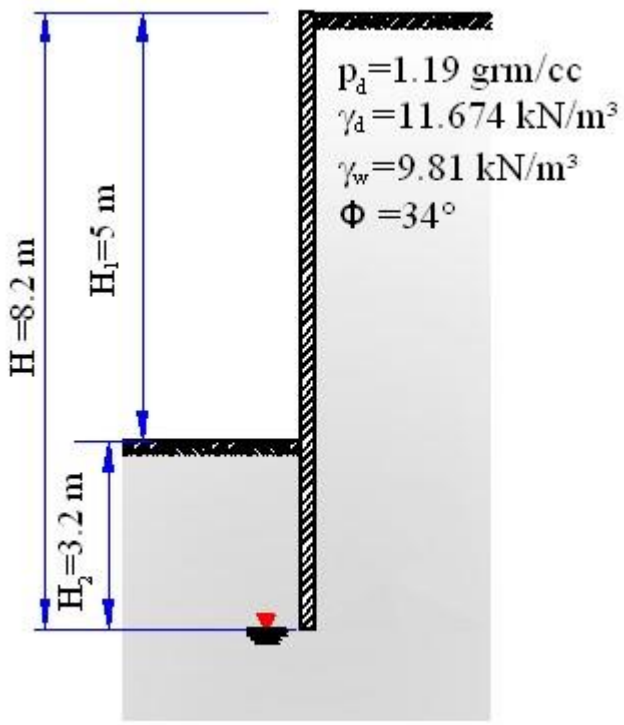
$$t_r = \frac{2L}{c} = \frac{2(650)}{1438.75} = 0.903$$

$$Since\ t_c > t_r, slow\ closure$$

$$p_h = \frac{2Lv\rho}{t_c} = \frac{2(650)(0.4865)(1000)}{3} = 210,831 Pa$$

$$p_h = 210.8 kPa$$

A cantilever sheet-pile 8.2m long supports a 5-m high dry sand with dry density of 1.19 g/cc and angle of shearing resistance of 34°. The pile is embedded to a depth of 3.2m. The water table is at the bottom of the sheet pile.



1. What is the maximum active force that can act on the sheet-pile in kN?

2. What is the maximum passive resistance that can act on the sheet-pile in kN?

3. What passive resistance must be mobilized for stability?

Solution:

$$\left[K_a = \frac{1-\sin\phi}{1+\sin\phi}\right]$$

$$K_a = \frac{1-\sin 34°}{1+\sin 34°} = 0.283$$

$$\left[K_p = \frac{1+\sin\phi}{1-\sin\phi}\right]$$

$$K_p = \frac{1-\sin 34°}{1+\sin 34°} = 3.537$$

1

Maximum active force :

$$F_a = 1/2\, K_a\, \gamma\, H^2$$

$$F_a = 1/2(0.283)(11.674)(8.2)^2$$

$$F_a = 111.07\, kN$$

2

Maximum passive resistance :

$$F_p = 1/2\, K_p\, \gamma\, H^2 = 1/2(3.537)(11.674)(3.2)^2 = 21141 kN > F_a\ (OK)$$

3

Maximum active moment, $M_a = F_a \times H/3$

Maximum active moment, $M_a = 111.07(8.2/3) = 303.59\, kN-m$

Maximum passive moment resistance, $M_p = F_p \times H/3$

Maximum passive moment resistance, $M_p = 211.41(3.2/3)$

Maximum passive moment resistance, $M_p = 225.504 < M_a\ (\text{unstable})$

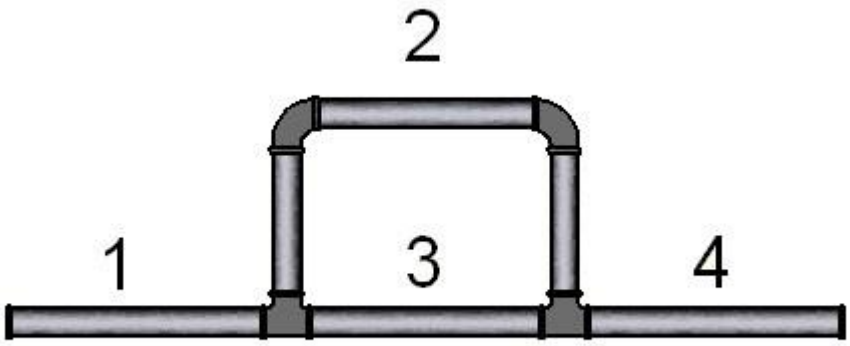
Required passive resistance :

$$\left[F_p y_p = F_a y_a\right] \qquad F_p\,(3.2/3) = 111.07\,(8.2/3)$$

$$F_p = 284.62\, kN$$

To solve for the required embedment depth :

Pipes 1, 3 and 4 are connected in series and 2 and 3 are connected parallel to each other. If the discharge of pipeline 4 is 5 liters/sec, find the discharge at pipeline 2.



Pipe	Diameter	Lengths	Friction factor
2	400 mm	4000 m.	0.020
3	300 mm	2000 m.	0.020

Solution:

$$hf_2 = hf_3$$

$$\frac{0.0826 f_2 L_2 Q_2^2}{D_2^5} = \frac{0.0826 f_3 L_3 Q_3^2}{D_3^5}$$

$$\frac{4000 Q_2^2}{(0.4)^5} = \frac{2000 Q_3^2}{(0.3)^5}$$

$$Q_2^2 = 2.107 Q_3^2$$

$$Q_2 = 1.45 Q_3$$

$$Q_2 + Q_3 = Q_4$$

$$1.45 Q_3 + Q_3 = 0.005$$

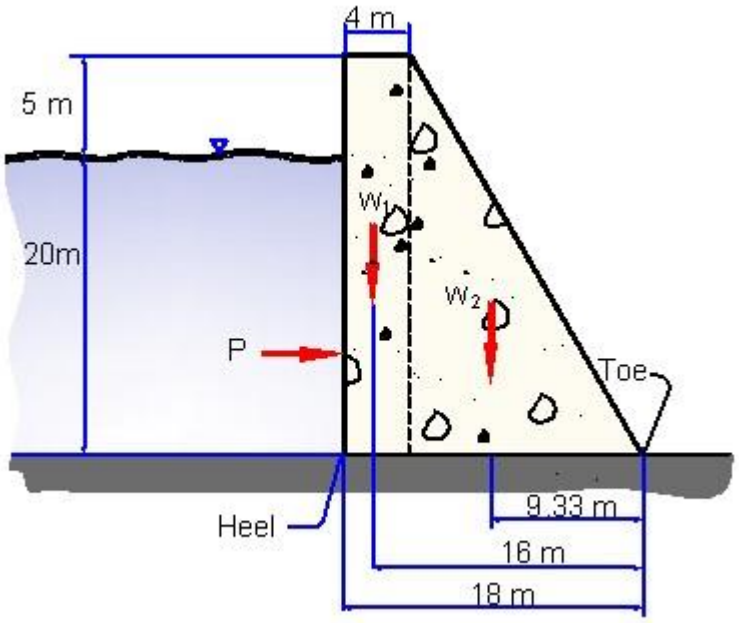
$$Q_3 = 0.002$$

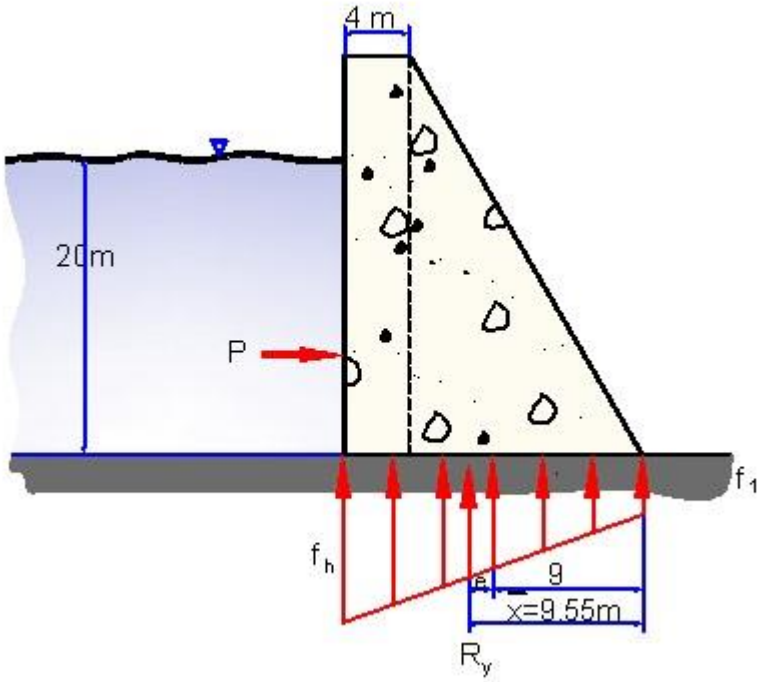
$$Q_2 = Q_4 - Q_3$$

$$Q_2 = 0.005 - 0.002$$

$$Q_2 = 0.003\ m/s.$$

A dam 4m. on top 18 m. at the bottom and 25 m. high has water 20m. deep acting on its vertical sides. What is the stress at the heel. Wt. of concrete = 2200 kg/m³.





Solution:

$$P = whA$$

$$P = 1000(10)(20)(1)$$

$$P = 200,000\ kg$$

$$W_1 = 4(25)(1)(2200)$$

$$W_1 = 220,000\ kg$$

$$W_2 = \frac{25(14)}{2}(1)(2200)$$

$$W_2 = 385,000\ kg$$

$$R_y = W_1 + W_2$$

$$R_y = 220,000 + 385,000$$

$$R_y = 605,000 kg$$

$$O.M. = P\left(\frac{20}{3}\right)$$

$$O.M. = \frac{200000(20)}{3}$$

$$O.M. = 1,333,333\ kg.m.$$

$$R.M. = 220,000(16) + 385,000(9.33)$$

$$R.M. = 7,112,050$$

$$x = \frac{R.M - O.M.}{R_y}$$

$$x = \frac{7,112,050 - 1,333,333}{605,000}$$

$$x = 9.55$$

$$e = 9.55 - 9$$

$$e = 0.55$$

$$f\,h = \frac{R_y}{B}\left[1 + \frac{6e}{B}\right]$$

$$f\,h = \frac{605000}{18}\left[1 + \frac{6(0.55)}{18}\right]$$

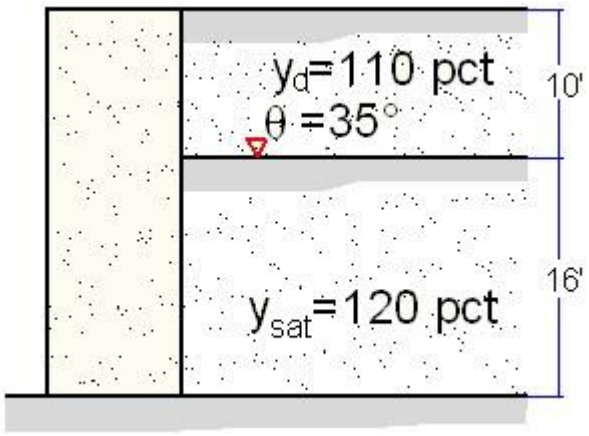
$$f\,h = 39,773\ kg/m^2$$

A retaining wall is required to retain a soil having a depth of 26ft. The dry unit weight of soil is 10 pcf with an angle of internal friction of 30°. Ground water table is located 10ft. below the level ground surface. The saturated unit weight of the soil below the water table is 120 pcf.

1) **Which of the following gives the value of the Reynolds number for a flow of 0.4 ml/sec. through the needle.**

2) **Which of the following gives the head loss.**

3) **Which of the following gives the force required a flow of 0.4 ml/sec.**



Solution:

1) **Resultant active force on the wall**

$$K_a = \frac{1 - Sin\theta}{1 + Sin\theta}$$

$$K_a = \frac{1 - Sin35°}{1 + Sin35°}$$

$$K_a = 0.271$$

$$P_1 = \gamma_s \, K_a \, h_1$$

$$P_1 = 110(0.271)(10)$$

$$P_1 = 298.1 \, psf$$

$$P_2 = \gamma_s \, K_a \, h_2$$

$$P_2 = (120 - 62.4)(16)(0.271)$$

$$P_2 = 249.8 \, psf$$

$$P_3 = 62.4(16)$$

$$P_3 = 998.4 \, psf$$

$$F_1 = \frac{(298.1)}{2}(10)(1)$$

$$F_1 = 1490.5 \, lb.$$

$$F_2 = 298.1(16)(1)$$

$$F_2 = 4769.6 \, lb.$$

$$F_3 = \frac{249.8}{2}(16)(1)$$

$$F_3 = 1998.4 \, lb.$$

$$F_4 = \frac{998.4}{2}(16)(1)$$

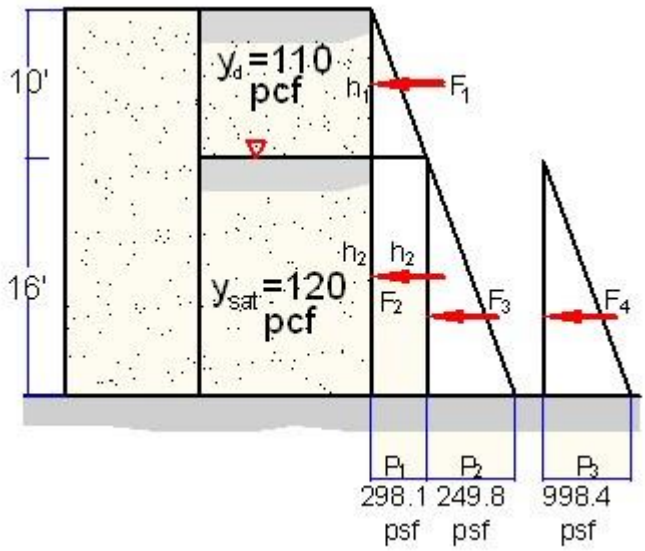
$$F_4 = 7987.2 \, lb.$$

$$R = F_1 + F_2 + F_3 + F_4$$

$$R = 1490.5 + 4769.6 + 1998.4 + 7987.2$$

$$R = 16245.7 \, lb.$$

2) Location of resultant force:



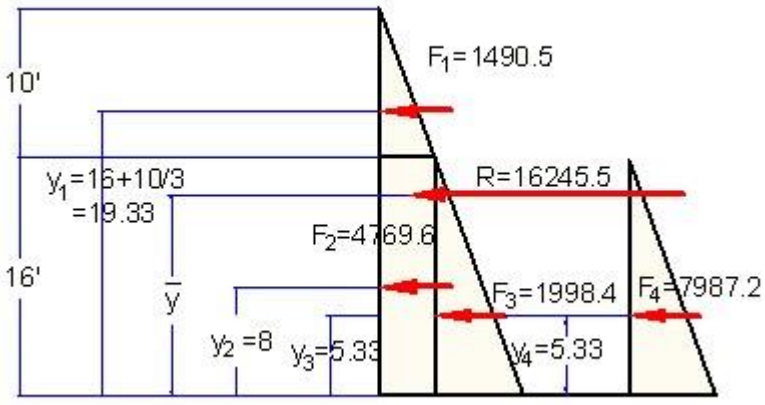
$$Ry = F_1 y_1 + F_2 y_2 + F_3 y_3 + F_4 y_4$$

$$16245.7\,y = 1490.5(19.33) + 4769.6(8) + 1998.4(5.33)$$

$$+7987.2(5.33)$$

$y = 7.40\ ft.$ *from the base*

3) Overturning moment developed:



Overturning moment = R_y

O.M. = 16245.7 (7.40)

O.M. = 120,218.18 ft-lb

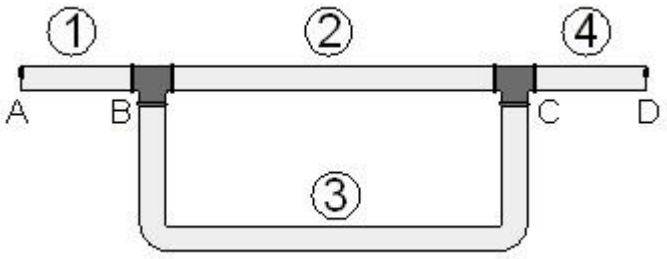
A pipe network consists of pipeline 1 from A to B it is connected to pipelines 2 and 2, where it merges again at joint C to form a single pipeline 4 up to point D. Pipelines 1, 2 and 4 are in series connection whereas pipelines 2 and 3 are parallel to each other. If the rate of flow from A to B is 10 liters/sec. and assuming f = 0.02 for all pipes, compute the following:

Pipelines	Diameter	Length
1	200 mm Ø	3000 m.
2	300 mm Ø	2200 m.
3	200 mm Ø	3200 m.
4	400 mm Ø	2800 m.

1) **Rate of flow of pipeline 3.**

2) **Rate of flow of pipeline 2.**

3) **Total head loss from A to D.**



Solution:

[1] Rate of flow of pipeline 3 :

$$Q_1 = Q_2 + Q_3$$

$$Q_1 = Q_4$$

$$hf_2 = hf_3$$

$$\frac{0.0826 f L (Q_2)^2}{(D_2)^5} = \frac{0.0826 f L (Q_3)^2}{}$$

$$\frac{2200 (Q_2)}{(0.3)^5} = \frac{3200 (Q_3)^2}{(0.2)^5}$$

$$Q_2^2 = 11.045 Q_3^2$$

$$Q_2 = 3.323 Q_3$$

$$Q_1 = Q_2 + Q_3$$

$$0.01 = 3.323 Q_3 + Q_3$$

$$Q_3 = 0.00231$$

$$Q_3 = 2.31 \ liters/sec.$$

[2] Rate of flow of pipeline 2 :

$$Q_2 = 3.323 \ Q_3$$

$$Q_2 = 3.323(2.31)$$

$$Q_2 = 7.69 \ liters/sec.$$

[3] Total head loss from A to D :

$$hf_1 = \frac{0.0826 f L Q_1^2}{D_1^5}$$

$$hf_1 = \frac{0.0826(0.02)3000(0.01)^2}{(0.2)^5}$$

$$hf_1 = 1.55 m.$$

$$hf_2 = \frac{0.0826(0.02)(2200)(0.00769)^2}{(0.3)^5}$$

$$hf_2 = 0.088 \ m.$$

$$hf_4 = \frac{0.0826(0.02)(2800)(0.01)^2}{(0.4)^5}$$

$$hf_4 = 0.045 \ m.$$

Total head loss from A to D :

$$HL = hf_1 + hf_2 + hf_3$$

$$HL = 1.55 + 0.088 + 0.045$$

$$HL = 1.6838 \ m.$$